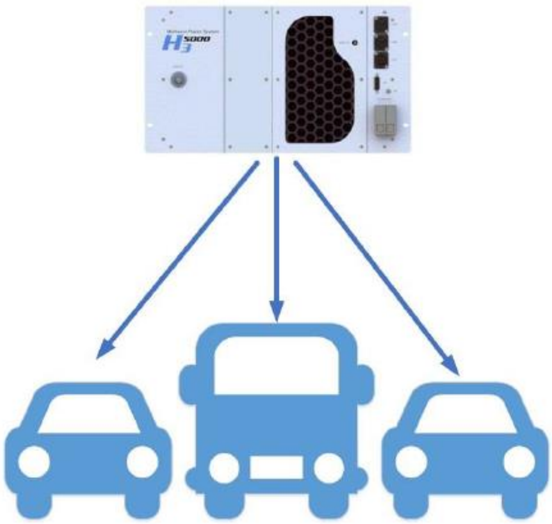
Modular Energy Carrier concept MECc



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1. Introduction of MECc project

1.1 Project details

Project title	Modular Energy Carrier concept
Project identification (program abbrev. and file)	MECc – project number: 64012-0154
Name of the programme which has funded the project	The Energy Technology Development and Demonstration Program, EDDP.
Project managing company/ institution (name and address)	Insero A/S (previously Insero E-Mobility A/S) Chr. M. Østergaards Vej 4a 8700 Horsens
Project partners	ECOmove, Insero A/S & Serenergy
CVR (central business register)	32654533
Date for submission	07-04-2017

1.2 Short description of project objective and results (1p)

The project aims to design and integrate a range extender concept into the modular vehicle platform in a battery electrical car. Hereby, a flexible configuration, clean emission, short refuelling time, long range, independence of charging infrastructure, exploitation of residual heat, high efficiency and a longer life of batteries is achieved.

In the project, a battery electric vehicle was retrofitted with Methanol fuel cells, approved for road use in Denmark and tested with a relevant customer. The customer was so pleased that following the project conclusion the vehicle remained in service on commercial terms next to other vehicles.

1.3 Executive summary

The key for the energy transition toward 100% non-fossil fuels is to bring electricity into the transportation sector. Moreover, this should be done in a simple way ensuring that storage and distribution of fuel is not costly and cumbersome.

Methanol can be a form of liquid electricity by combining biomass and hydrogen from electricity into a liquid form that can be stored and distributed with ease and in already existing infrastructure. The conversion of electricity to methanol and distribution has been demonstrated and is used intensively in e.g. China where 6% of all transportation fuel is methanol.

However, the key is to convert the methanol efficiently into electricity without harmful emissions in the form of particles, noise and vibrations. This is what the MECc project has demonstrated is feasible!

The MECc project took a battery electric car and made it into a hybrid vehicle with a reformed methanol fuel cell based on high temperature PEM. The vehicle was approved for road use and tested with customers who could see advantages in long operation hours and continued use in an urban environment.

The commercial benefit of a methanol fuel cell vehicle is the operation costs versus that of a combustion engine variant of the same vehicle. The fuel cost savings are 30-40% over diesel and even more over gasoline. This is based on the efficiency of the fuel cell and the relative cost of the fuel. The cost savings are based on fuel with tax on an energy basis and not volume which is the current legal frame in Denmark resulting in 4 times tax on the Methanol/water mix.

The cost of the vehicle is currently higher than a combustion variant due to the extreme difference in production volume; 1 VS 7 million. However, this can be offset and by reducing the size of the battery pack and fuel cell peak power, the drivetrain can be cost competitive with combustion variants in the appropriate segments.

The Methanol Fuel Cell concept should be seen as a supplement to battery electric vehicles and will take over when the pure battery electric platform is not feasible anymore due to range, weight, cost or charging time.

The MECc project has been an important milestone and several commercial projects with vehicle OEM's has been the outcome of the project, resulting in job creation and export revenue. The main conclusions from the concept will contribute to the energy transition and the first commercial vehicles are around the corner.

2. Project objectives

The objective of the MECc project is to extend the driving range of a battery electric vehicle (BEV) by designing and integrating a fuel cell range extender concept based on methanol as a modular energy carrier. The battery electric vehicle is a retrofitted Fiat 500 gasoline car, which is called 500e and converted by eCar. During the MECc project, the battery electric vehicle has been rebuilt to a hybrid car with a methanol fuel cell, and therefore the concept car is called a Fiat 500e-Hybrid. The prototype of Fiat e500-Hybrid has been approved as a road machine in Denmark.

The green performance of the vehicle will be improved by fuelling with bio-methanol, which is produced from renewable sources. However, the production cost and the overall economy of bio-methanol is higher than methanol, as methanol is produced in larger plants, easier to produce, cause to lesser store capacity and logistic handling than bio-methanol.

The battery electric vehicle with a methanol fuel cell range extender has the following technical advantages[1]:

- Flexible configuration of vehicle
- Refuelling time is less than 3 minutes.
- Range of the vehicle is up to 800 km in accordance with NEDC Urban. Four times longer than an average electric vehicle
- Cabin heating independent of the battery, as waste heat is applied for both cooling and heating of the cabin.
- Superior WtW, and energy efficiency of the vehicle is more than 80%.
- A significantly longer lifetime of the batteries due to improved State-of-Charge (SOC) management.
- Reliable on-board reforming of liquid fuel.
- A simple, efficient and clean solution enabling BEV's to reach the same level of adoption as Internal Combustion Engines (ICE) without the need for massive infrastructure investments.

2.1 Tasks for partners and suppliers

Partners	
Serenergy	• Development of a methanol fuel cell system. • Rebuild the battery electric vehicle • Integration of the methanol fuel cell system in the vehicle
Insero A/S	• Project management • Plan and conducting user test of the vehicle
Sub-suppliers	
eCar	• Conversion of an international combustion engine in a Fiat 500 to an electrical car (eCar 500)
Danish Technical Institute	• Counselling regarding approval of the vehicle by Danish Transport, Construction and Housing Authority
Delta	• EMC/EMI radio noise measurements

[1] http://mecc.dk/about-mecc/the-purpose/

2.1.1 Work packages during the MECc project

The MECc project has been conducted as illustrated in Figure 1. The concept development process of the MECc vehicle has been developed as an iterative process where risks have been identified and the supplier of vehicle has been changed. The first concept design has been developed in cooperation with ECOmove with use of the QBEAK EV platform (the red boxes). ECOmove abandoned the cooperation, and it was necessary to find another supplier of an electric car for continuing the MECc project. Afterwards, MECc partners collaborated with eCar Sweden, who delivered an electric Fiat 500 for converting to a hybrid car with methanol fuel, and the second concept hybrid car was designed (the green boxes). For concept designs, cf. Appendix 1a & 1b – *Concept description*.

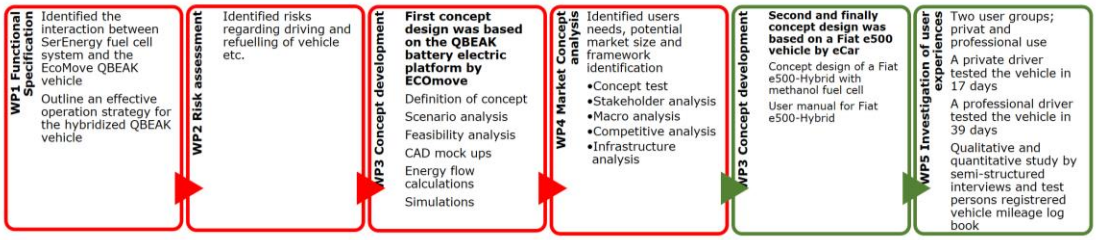

Figure 1 Conducted work packages and work tasks during the MECc project

3. Project results and dissemination of results

3.1 Concept development

Figure 2 illustrates the concept development of the battery electric vehicle with methanol fuel cells. The red arrow illustrates the first developed concept design and the green arrow the final prototype design. The development of the concept of a battery electric vehicle with an integrated fuel cell range extender based on methanol started in collaboration with ECOmove. ECOmove supplied the project with the QBEAK EV platform, which was rebuilt to a battery electric vehicle with methanol fuel cells in collaboration with Serenergy. During the project, ECOmove discontinued as partner in the MECc project after a proof of concept test was conducted. For description of the concept, cf. Appendix 1a & 1b – *Concept description*. The concept development is defined in document*; WP3 – Concept development (EM).*

The development of the final prototype of a battery electric vehicle was conducted with an alternative supplier of electric vehicles, eCar Sweden, who has retrofitted a Fiat 500 to an electric car by replacing the gasoline engine with an electric motor and batteries. During the MECc project, the electric Fiat 500 (Fiat e500) has been converted to a hybrid by integrating the car with methanol fuel cells. Serenergy has converted two Fiat e500 to Fiat e500-Hybrid. For description about the concept process, cf. Appendix 2a – *Functional Specification* and Appendix 2b - *Brugermanual for MECc Fiat 500-Hybrid med Methanol Brændselscelle.* The Fiat e500-Hybrid has been tested for electromagnetic capability after installation of fuel cells, and the hybrid car has afterwards been approved by the Danish Transport, Construction and Housing
Authority for driving at public roads. However, the driver of the prototype must be instructed by a selected employee from Serenergy A/S before driving, just as the car cannot be sold.

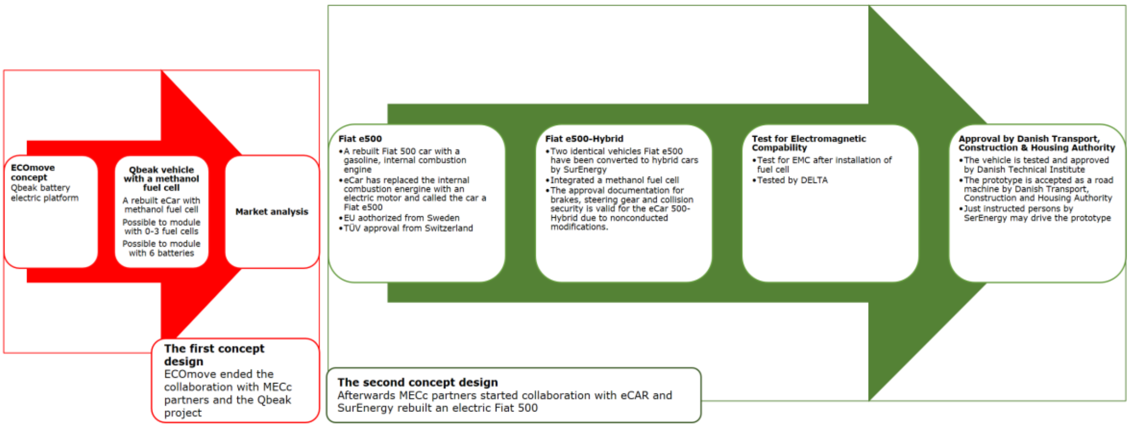

Figure 2 Concept development process during MECc project

3.1.1 First developed MECc concept and technical components

Vehicle frame – QBEAK by ECOmove

The MECc concept is based on a combination of two new technological products for developing a Range Extended electric vehicle, respectively QBEAK by ECOmove, a battery electric platform, and a HT-PEM fuel cell with methanol as fuel. The MECc concept is advanced by modulate batteries and fuel cells. Detailed description of the concept, cf. *WP3 – Concept development (EM).*

	The vehicle is based on a rolling chassis concept from QBEAK by ECOmove, where the energy source is fixed in 6 (2x3) energy slots in the chassis, cf. Figure 3. The frame is designed to contain 6 long batteries with the dimensions; 1933.5mmX403mmX227.88mm. The batteries can be installed in the back of the vehicle and connected to the front of the vehicle. The Electrical engines

Figure 3 Vehicle frame from QBEAK by ECOmove	is placed in each wheel and powered from an energy storage placed within the frame.

Fuel cell engines – HT-PEM fuel cell

The fuel cell engine is based on a high temperature fuel cell and a methanol reformer, cf. Figure 4. The two components are closely integrated and when possible, Balance Of Plant (BOP) is integrated for single module operation. The effect of the fuel cell modules is 5kW, but it is possible to scale the power up and down from 5, 10 and 15kW using more units. The performance curve based on initial test data illustrates that fuel cells with a 3.2 kW electrical power output obtain over 40% system efficiency, cf. Figure 5.

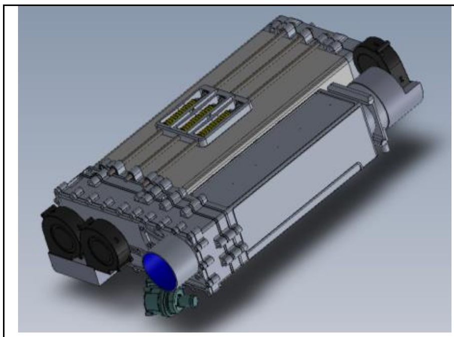

Figure 4 A CAD drawing of a Serenergy fuel cell engine. The dimension of the fuel cell engine is 700mmX300mmX200mm.

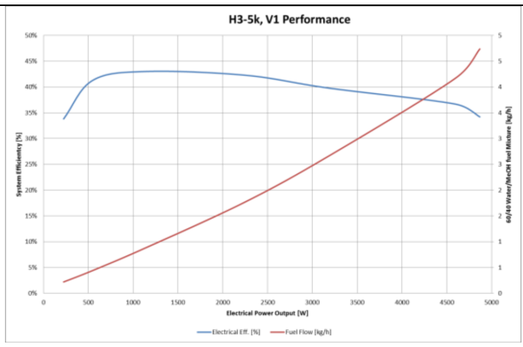

Figure 5 The performance curve of a Serenergy fuel cell

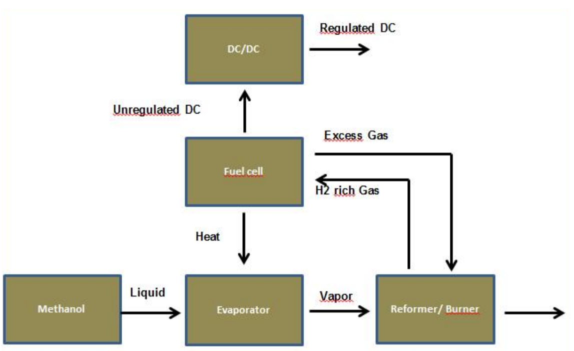

Figure 6 RMFC system. A system of a fuel cell and a methanol reformer

Figure 6 illustrates the RMFC system, the incineration of methanol for forming gas to the fuel cell. The Urban cycle (1100 W contin-ues/average) norm consume 0.061 kWh/km, which corresponds to a fuel consumption on 19.7km/L. A 40L fuel tank, excluding the battery capacity, can result in 785km driving range. Energy capacity in 1-3 battery models will provide to 50-140 km range of the vehicle. A fuel cell consists of a methanol buffer tank, methanol feed pump, methanol circulation pump, coolant expansion tank, control unit, power conversion assembly and insulation.

QBEAK platform with batteries and fuel cells

Figure 7 illustrates the chassis of the QBEAK platform, and Figure 8 illustrates the modularity of the batteries and 5kW fuel cell modules. The left side of the vehicle frame is designed for fuel cell systems and the right side is for batteries. The modular system can be designed depending on requirement for speed and range. It is possible to modulate the platform with one 70L methanol fuel tank, 1-2 HT-PEM fuel cell modules and 1-3 battery modules.

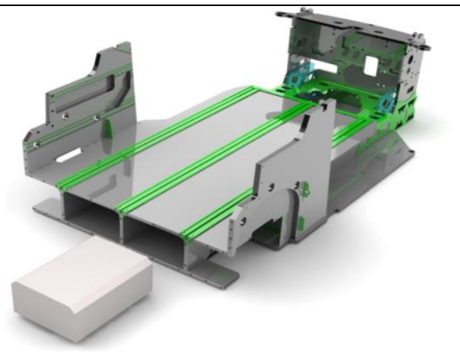

Figure 7 The chassis from QBEAK and a HT-PEM fuel cell

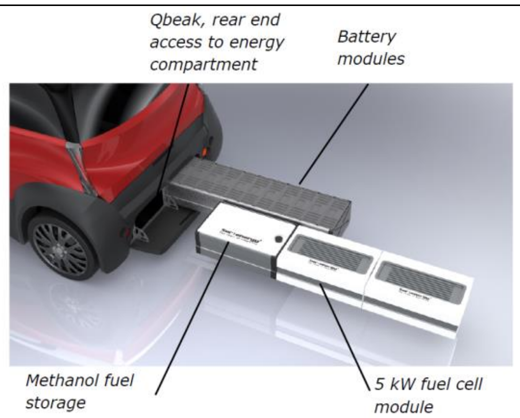

Figure 8 Possible modularity with batteries and fuel cells

module.	

3.1.2 Second developed MECc concept and technical components

The prototype for the Fiat e500-Hybrid car is illustrated in Figure 9. The gasoline engine has been replaced with an electric motor, but the manual gear system has been maintained. The main battery for driving is placed under the bottom of the car. The original 12V system has been maintained, but the generator has been replaced with a charger, which can maintain the 12V system with power from the main battery. The car has an electric water heater installed, which heats the cooling water for heating the cabin. On a general level, the focus during the rebuild-process of the Fiat e500 has been on mechanical strength and safety for passengers in the car.

The Fiat e500-Hybrid is licensed as a car for two. Figure 10 illustrates that the original boot and back seats are included for the technical room with the fuel cell system, but the top of the technical room can be applied for baggage. As for safety, the technical room fuel cell is separated from the cabin with a lightweight and mechanical strong construction of 25mm “alucore” plate. A plate of two aluminium sandwich plate with aluminium honeycomb between the plates.

Figure 9 A rebuilt Fiat e500-Hybrid car

Figure 10 The cover of the technical room, which is placed at boot and back seats in the Fiat e500

Figure 11 illustrates the technical room with fuel cell system (the white box), which weighs 75kg. The fuel tank (the stainless-steel box) is a 89L tank and it is CE approved. The fuel tank is placed in front of the rear axle for increasing the security regarding collision from behind. An air intake is connected to the technical room, applied as process air and cooling the system and a mechanical exhaust device is placed under the car. The mechanical exhaust starts automatically, when the fuel cell is activated. The cooling system for the fuel cell is based on both an internal air cooling and external water cooling system. The external water cooling system is primarily applied for using the waste heat for cabin heating, and the fuel cell can supply with internal air cooling. Otherwise, the waste heat will be delivered to a cooler with mechanical exhaust device.

Figure 12 illustrates the electric system with battery and the fuel cell module. The blue line is the power connection between the components, and the green is the communication and control connection. The battery monitor (ECU/BMS) monitors and controls the battery, and the BMS interrupts respectively the charger or the fuel cell module connections to the battery, if the connection can damage the battery. The fuel cell Module is a Serenus H3-5000 with a 5kW output effect.

Figure 11 The technical room

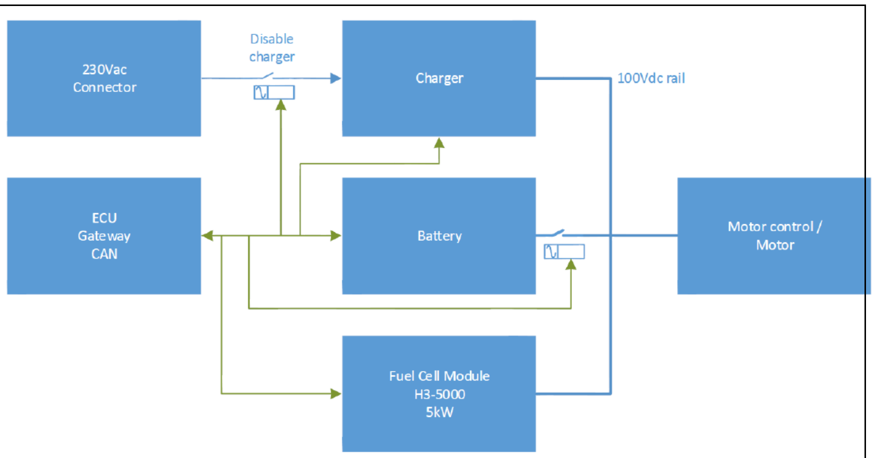

Figure 12 Electric system

Control and Charging of battery with fuel cells

The user can charge the battery by connecting a charger cable or manually activate (and deactivate) charging of the battery with a switch at the control panel in the car, cf. Figure 13. A control computer is placed in the car, which communicates with BMS for securing the right condition for the battery. The charge level (SOC) must be between 10-90% before the BMS permits charging and sends signals to the fuel cell. The charging up to 100% SOC is only possible with a cable, as the battery will both be charged and the battery cells will be balanced.

The fuel cell can also be managed and monitored by a tablet, which is mounted in the car, as the fuel cell has an integrated WLAN web connection. The web page gives information about fuel cell status, output effect, fuel consumption, sensor values and any occurred errors. For further descriptions about charging with fuel cells, cf. *Brugermanual for MECc Fiat e500-Hybrid med Methanol Brændselscelle*.

Figure 13 The control panel between the seats. A switch for activating the fuel cell, a control light for activation level of the fuel cell, a switch for activating cabin heating and the tank meter for fuel in the fuel cell.

3.1.3 Refuelling of Fiat e500-Hybrid

Figure 14 illustrates that the Fiat e500-Hybrid is installed with a Spill free system on the tank pipe connection to avoid user contact with methanol. The tank is a closed system, which is why the system has a separate ventilation with a filter in the bottom of the car. The filter has an active coal, which absorb toxic methanol damps. For more detailed description, cf. *Brugermanual for MECc Fiat e500-Hybrid med Methanol Brændselscelle, chapter 4*. The infra-structure has been developed by a separate EDDP project – Green Methanol Infrastructure.

Figure 14 Systems for refuelling of vehicle

3.1.4 Risk assessment and precautions for a hybrid vehicle

A risk assessment has been conducted and the car has simultaneously been optimized during the project period, when risks have been identified.

One of the most relevant risks is electric shock during reparation and service of the vehicle, as the main battery has a voltage at approximately 100V. Therefore, the precaution is that the user of the car should not open the technical room, and the cover to the technical room must be closed and the seam must be sealed with tape.

The second risk is that users of the vehicle get in contact with the blending of methanol and water for the fuel cell, as methanol is toxic. Therefore, the tank pipe has been designed with a spill free system to avoid user contact with the fuel blending, cf. chapter 3.1.3.

The third risk is mechanical danger in case of collision, where the vehicle can burst into flames and emit exhaust gasses. Therefore, the fuel cell and tank are separated from the cabin with an “alucore” plate. The fuel cell is secured with steel tape to the chassis of the car. Furthermore, the seam in the technical room has been jointed for securing a gas free cabin, cf. 3.1.2. For assessed risks, cf. Appendix 3 – *MECc FMEA*.

3.2 A Concept Test

Private and professional users' experiences with the concept car have been investigated for targeting their needs in the future. The user experiences have been investigated by a qualitative study based on comprehensive interviews and results from driving journals. First, the private user used the car for 17 days and afterwards the professional user (Just Eat) used the car for 39 days for business purposes. The data from the interviews have been categorized into the following four variables:

1. Use of the vehicle during the test period
2. Adding fuel
3. Range
4. Driving experiences

The following gives a general summary of both the private and business test driver's user experiences:

- Test drivers experience that the car is not too speedy or good at accelerating compared with gasoline or diesel cars
- The MECc car is best for driving in cities and to a lesser extent at the motorway, as the high pace drains the battery
- The users say that it requires adaptation to shift gear in a MECc car, and at the time a gear shift is performed by a gut feeling.
- The lack of engine noise is experienced as positive, but the motor sound is missing in correlation with the need for shifting gear.
- The private driver wants clear information in the car that it is connected to the grid and a possibility to turn on the fuel cell with an app when it is necessary.
- The private driver wants a battery with an increased range, before it would be possible to replace the private car, which is applied for longer distances. Furthermore, there will be a need for improving the infrastructure with methanol filling places.
- The professional driver, Just Eat, says that the vehicle should be optimized with a larger boot, if one of Just Eat delivery cars was to be replaced with a MECc car.
- The professional driver estimates that a MECc car will result in a little longer delivery time, as the MECc car has a lower acceleration speed. The extra time has not been defined.

The participants from the full concept test agreed that it was a good idea to implement in the Fiat e500-Hybrid, but the vehicle and concept should be in a mature state with a full track record and service package behind. Instead, the test users want a proven technology and neither of them are interested in investing in their own infrastructure for a hybrid car on methanol fuel. For more information on the demonstration, cf. Appendix 4 – *MECc - User experiences.*

3.3 Market concept analysis

3.3.1 Research design

The purpose of the market concept analysis was to define the following elements, which can impact the market development for the MECc vehicle:

- Needs of the future users
- Potential market size
- Needed framework

The analysis process was to identify potential business models based on different realization scenarios and entry markets. The market concept analysis has been developed based on different frameworks, cf. Figure 15.

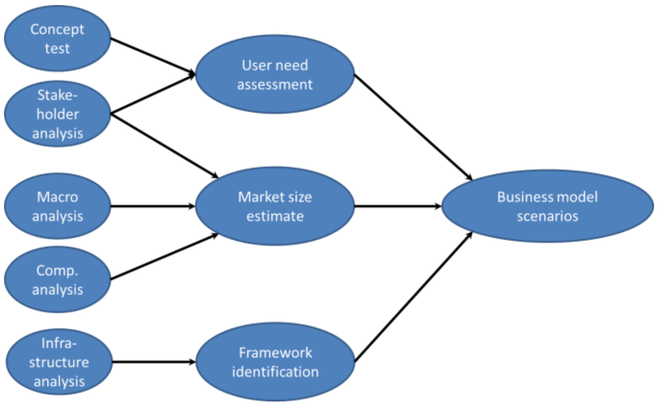

Figure 15 Analysis process for identifying business models for MECc project

3.3.2 User types and market needs

The need analysis is based on a matrix rating of the 5 different segments (B2B, B2C, B2M, B2G and B2E) with 22 user types to conclude on the most favourable market segments and user types, cf. Table 1. The market segments with a rating of 7 or above is highlighted, and the user types have some demands and attributes in common. For Matrix rating, cf. Appendix 5 – *Market Concept Analysis*

- High-cost infrastructure for battery electric vehicles for fleets
- Importance of alternative options for instance energy storage
- High frequency of usage for ROI
- Total cost of ownership (TCO) is 'king'
- Importance of economic efficiency
- Significant importance for CSR performance.

The need analysis indicates that the *B2B* segment is the overall most favourable market orientation with the greatest opportunities for the concept, cf. Table 1. Most of the user types within the *B2B* segment are rated high comprising B2B car-sharing, company fleets, rentals, car-sharing providers, and airport ground transport. The segments of *B2B* and *B2G* combined are also rated as favourable market segments. Furthermore, city-level public transport and administration (B2M), and postal service and internal transportation (*B2G*) are highly rated user types. The user types of non-governmental organizations (*B2E)* is rated as favourable, whereas military has a relative low rating, however it is a market segment with future potential.

B2B	B2C	B2M (municipality)	B2G (government)	B2E (extreme)
Taxis **B2B car sharing** **Company fleets** **Rentals** Tourists and travel **Car sharing providers** **Airport ground transportation**	Mass market (vehicle owners) Private leasing Car sharing Students Young professionals Disabled	**City-level public transportation** Home care Retirement homes **Administration**	**Postal service** **Internal transportation** Royal vehicles	Military **Non-governmental organizations**

Table 1 Defined market segments and the most relevant market segments are highlighted

3.3.3 Market strategy

Further segment analysis shows that segment feature priorities and interest are very different from segment to segment. The segment analysis is therefore primarily based on segment behaviour in the Danish market and the results are assumed to reflect other European markets. See the tables below for investigating each segments demand and requirement.

B2B Business to business

Car sharing	The market for car sharing is expected to increase, both within B2B (joint office facilities) and in the public space. Car sharing companies are usually smaller than rental companies with shorter decision-making processes, and has an interest in decreased TCO. Furthermore, some car sharing companies has a green profile, which means that a higher TCO can be accepted.
Company fleets	Company fleets increasingly consist of personal company cars as a part of a salary package. This market is very hard to enter, especially because employees are usually very conservative in relation to alternative technologies. To convince employees, the car should match a long list of quality criteria.
Rentals	Rental car firms are very hard to approach. Most rental-car-firms buy their cars via their international HQ, which makes framework agreements directly with the OEMs. Prices are low and based on buy-back agreements. A market opening is on the national level, where some rental car companies have the mandate to test new technologies in the search for new market value (e.g. Avis/Nissan Leaf in DK).
Airport ground transportation	Airport ground transportation is an interesting market. Passenger cars is a very limited cost item for airports, and especially airports with a strong CSR profile, see an opportunity to reduce particle emissions through their car purchases despite its results to higher costs. The way to enter the market is airport trade shows and by contacting fleet managers or CSR departments.

B2M Business to municipality

City-level public transportation	The (B2M) City level public transport segment is almost non-existing and therefore not included in this analysis.
Municipalities /public administration	Municipalities (public administration) increasingly centralize and optimize fleet management. Depending on the strategy of the specific municipality, some might be forced to buy EVs when possible, some will accept a minor increase in TCO and some are solely TCO focused. The way to approach is the fleet manager, sustainability department, and/or through networks relevant to these persons.

B2G Business to government

Postal service	Postal services are cost focused. Price must be competitive to conventional cars and full service agreements must be a part of the offer. However, special tenders for EVs could also cover the MECc vehicle. Contact the technical/fleet division can possible add extra criteria favouring the MECc vehicle.
Internal transportation	Regions, government agencies, authorities and ministries have a lot of specialty vehicles, vans and buses, as well as quite a low rate of substitution. The vehicle area generally does not receive much focus, as it is rarely a part of core services. A very diverse segment, also with regards to fleet management (first point of contact). Segment might become more interesting, if there is a political pressure for 'green' purchases.

B2E Business to extreme

Non-governmental organization	NGOs is the most diverse segment, and the primary aspect that unite organizations in this field is their fight for a cause. Excluding organizations that have a green profile, purchasing green vehicles (at a higher cost) will need an active decision to move funds away from fighting for their cause to administration/operations. The most interesting parts of this segment are therefore organizations with a 'green' agenda and possibly organizations where a car that is not dependent of fossil fuels would have interest. The way in is through a fleet manager.

3.3.4 Macro analysis

The macro analysis is based on data from 63 countries, which are divided into seven segments, cf. MECc Market Concept analysis. 13 countries out of 63 have been selected because of relevant parameters regarding political commitment, geographical proximity, PHEV sales, refuelling availability or interest in the MECc project, cf. Table 2.

Size of affluent countries or with decent GDP	Defined countries	Highlighted segmented country	Macro analysis
Large sized affluent countries	15	Finland Sweden	Interest in biofuels and geographical proximity
Medium sized affluent countries	3	Iceland	Methanol production and tests of several alternative fuels e.g. hydrogen.
Small sized affluent countries	9	Denmark	The domestic market and political understanding
		Netherland	Increasing sale of Plug-in Hybrid. Both Mitsubishi's Outlander PHEV and BioMCN produces high quality bio-methanol.
Micro sized affluent countries	15	Luxembourg	A transit country where all road users need range, and close to BioMCN regarding refuelling
		Monaco	Interest in green energy and cars
Large countries with decent GDP	5	Poland	Decent sales numbers of Plug-in Hybrids and legislations give incentives to invest in biomass power production
Medium/small countries with decent GDP	7	Latvia Lithuania	Political willingness and commitment in the EV sector. Especially in the hybrid market.
Micro countries with decent GDP	9	Aruba Mauritius	Interest in the MECc project since press announcement in 2012.

Table 2 Macro analysis based on 13 selected countries out of a group of 63

The market share in Europe

The total market share of 10 countries (Finland, Sweden, Iceland, Denmark, the Netherlands, Luxembourg, Monaco, Poland, Latvia and Lithuania) is approximately 711.000 PHEV and EV's. The desired market share in these segments is 0.1 % of the total market. A total market share of 0.1 % corresponds to 711 cars distributed over the 10 countries. It is a growing market, and the total sales per year (to date) is approximately 223.000 PHEV and EV's, and the market share will be 223 cars in a year. It's a small share but would potentially be enough to set up a prototype production.

3.3.5 Competitor analysis

In this competitor analysis, the focus has not been on companies, but on technologies instead. The reason for this is that the market of range extenders is in an early stage, and the preferred choice of technology is not determined.

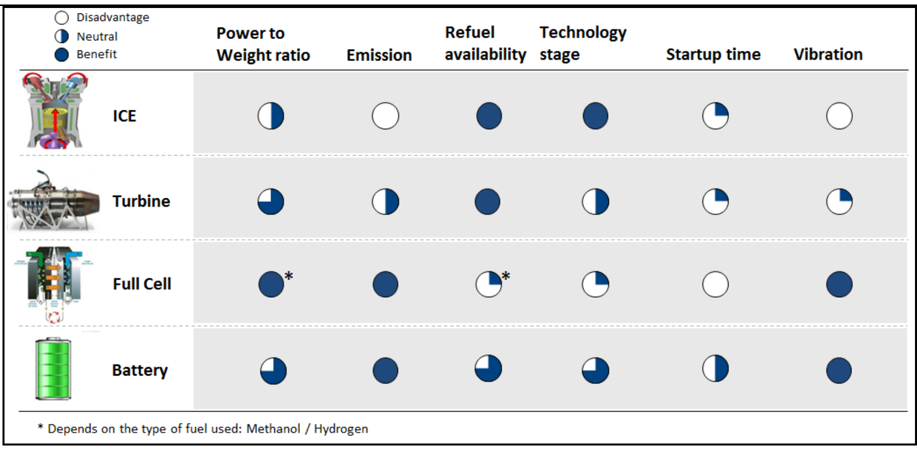

Table 3 Technology mapping of range extenders

This mapping of range extender technologies cannot be used as a scoreboard to calculate the "best" range extender technology. The technologies are very different in operation, fuel, emission etc. The mapping should be used to give an indication of how the specific technology operates and its strongpoints. The third generation of range extenders with mini turbines and fuel cells seems to have great advantages in the future due to lower pollution, cost, weight and size, and improved reliability, life and fuel independence. The disadvantages are startup time of two minutes or more and problems with noise that can be hard to suppress. Several ICE second generation range extenders using pistons are now designed to work as a range extender, in parallel with the first fuel cell and mini-turbine third generation range extenders being implemented in a few cars and other on-road vehicles. However, it's believed that almost all hybrids will use something other than the ICE technology2 in the future.

3.3.6 Business model canvas

The business model is investigated with focus on five of the nine dimensions in the Business Model Canvas by Osterwalder. The five dimensions are defined in following:

3.3.6.1 Value Propositions

The unique value proposition offered by the MECc concept can shortly be summarized in a compact vehicle with long distance CO_2 neutral travel possibilities with minimal emissions and quick refilling allowing for clean, free mobility. The infrastructure is based on the existing systems with liquid fuels and can therefore reuse the already established gasoline stations as fuelling stations with minor adjustments.

[2] Harrop, Dr. Peter; *Range Extenders for Electric Vehicles 2012-2022*; IDTechEX

The vehicle is also installed with a system to reuse excess heat to allow for cooling or heating of the cabin without influencing the range of the vehicle, hence providing seamless driving pleasure no matter the weather.

For the next generation, the MECc concept should be considered applied to larger vehicles as these tend to be used more regularly for long distance driving, hence providing a bigger incentive for the use of the fuel cell system. A niche seems to be available in mid-sized logistic vehicles, where no electric solution is applicable at the current time.

3.3.6.2 Key Partners

To realize the potential in the MECc concept, key partnerships are essential for the main organization behind, Serenergy. These key partnerships are relevant for both the creation of an initial roll out fleet as for larger scale deployment of the vehicles and are connected to the Customer segments and Channels.

Serenergy is a Danish-located, German owned company that produces modular HT-PEM Fuel Cell systems designed to run on methanol. This is the key technology to realize the MECc concept in combination with the vehicle.

Potential key partners can be summarized to the following:

Type	Example	Role
Vehicle producer	Nissan, Audi, eCar Sweden, etc.	Provide a rolling platform on which the MECc system can be installed. Provide technical help to secure the right communication on the vehicle.
Service organization	OEMs, Bosch, Kettner, etc.	Quick handling of breakdowns and failures. This point is an important order qualifier for several fleet owners. For small fleets, this partner could be local, but for roll out to a larger area, this needs to be a national organization.
Vehicle approval organization	TÜV, Danish Technological Institute, SGS, etc.	Since no direct standard for approval of this type of vehicle exists, it is important to collaborate with an approval organization to secure, that the vehicles can be sold legally.
Gasoline company	Shell, Circle K, Q8, Total, etc.	In order to set up a functional infrastructure, the collaboration with at least one gasoline company is important, as they will be making the investments in establishing it.
Policy makers	Political parties, lobbying organizations, branch organizations, etc.	Political support and subsidies for the new technology to gain sufficient infrastructure and realistic prices are necessary and will demand a strong political lobbying partner.

The key partners also play an important role in the upstream activities as they act as a quality sign for the solutions, convincing the potential buyers about the validity of the product. The history of vehicle production has seen several brands emerge just to die after a short number of years. In order to avoid being put in the same box as these, sufficient funding and official collaboration with large brands are necessary as well as a proven track record.

3.3.6.3 Key Resources

The main resource that is realized in the MECc project, and of importance for the rollout of the system, is the HT-PEM system that has been balanced for implementation in a vehicle. A significant part of this is the communication platform between the fuel cell module and the vehicle CANbus, where settling of charging strategies, access to state of charge and opportunity to charge without the vehicle being turned on are important to settle.

3.3.6.4 Customer segments

Several segments have been identified as relevant, where common denominators such as long daily driving range (exceeding that of an EV), strong focus on CSR and long investment horizons are the most important to be able to make a good product-need mix. In the table below, the most relevant segments identified are identified with potential market size and ease of entry into this as the main parameters. Table 4 illustrates that the most potential markets to enter would be public administration vehicles, airport ground transportation and car sharing. The first two would act as initial demonstration markets, as the organizations could be considered as patient users, where car sharing would be an investment in growing the market that is increasing through the focus on Mobility as a Service.

Segment	Market size	Market penetration (ease of entry)	Market growth (tendency, 0-5 yrs.)
(B2B) B2B Car sharing	◔	◕	↗
(B2B) Company fleets	●	◔	→
(B2B) Rentals	◑	◔	→
(B2B) Car sharing providers	◔ *	◕	↗
(B2B) Airport ground transportation	◔	●	→
(B2M) Public administration vehicles	◕	◕	→
(B2G) Postal services	◑	◑	↘ **
(B2G) Internal transport	◑	◑	→
(B2E) NGOs	◔	◔	→

* Big difference from country to country. DK evaluated as average.
** Letter delivery in small vans is decreasing. Parcel delivery in trucks and larger vans is increasing.

Table 4 The overview of segment, market size, penetration and growth

3.3.6.5 Channels

The three identified potential markets are all characterized with a relatively easy entry into the market. In all three cases, a direct personal connection to the person in charge of the fleet will be necessary and the opportunity to test the vehicle before investing in it. The main channel is therefore through personal contact. The potential of getting supporting channels to inform about and validate the technology lies in a combination of utilizing partners' brand and communication platforms and through showcasing the technology in trusted medias such as car magazines.

4. Utilization of project results

4.1 Challenges and optimization of the MECc Concept

Overall, the concept of the methanol fuel cell as a system to work as a range extender is interesting and acceptable as a technology for all the interviewed parties. The challenge lies in modelling a business model that will allow for a positive TCO compared to competitive solutions with lower costs, since economy is the most important bottom line for most industries.

The additional function of providing energy efficient cooling and heating is highly relevant, as it improves the working environment for the driver. Both logistic companies and home care organizations have a driving range, which could be covered by a fully electric vehicle. However more than 20 % of the trips differ from this range, which results in a need for a supplementary solution for the MECc concept. Furthermore, there is a need for a larger vehicle for logistic companies due to need of space, and establishment of both a service organization and infrastructure to support the technology, as none of the organizations are interested in costing their own infrastructure, but will rely on the public infrastructure. Additionally, none of the involved organizations in the initial concept test are interested in the first procurements of the solutions, as they want to have a proven technology for reducing costs, which increases the importance of the demonstration part of the MECc project in order to prove a high reliability.

The buying process in the organizations is centrally controlled, with influence from the drivers only when they have their own vehicle. Communication should be directed to the fleet manager and focused on the positive, flexible elements provided by the solution, low running costs, clean profile and increased driver convenience compared to pure electric solutions. Furthermore, the green performance of the MECc car can be improved by applying bio-methanol instead of methanol. However, bio-methanol is more expensive than methanol, but improved production and store capacities and an increased demand for biofuels can cause to decreased bio-methanol prices.

4.2 Framework identification

Three issues are needed to secure the production of vehicles with new drivetrains or fuel systems. First, the vehicle should improve the value to the customer compared to the value the customer already gets from existing vehicles. Secondly, the vehicle should be priced at a competitive level reflecting the value it offers. Third, an infrastructure to support the new technology should be available. The second and third issues are highly influenced by local politics in the countries. Methanol is only an applied fuel in the future, if the competitive situation is improved compared to gasoline and diesel, which demands top-down regulations e.g. tax reductions for a period. The vehicles should as well be supported in the same way as hydrogen fuel cell vehicles, since the technology is comparable in cost, even though the infrastructure is cheaper to establish. Without political or significant economic support, the new technology will not be able to disrupt the automotive industry that will continue to develop in the pace directed by the major OEMs.

5. Project conclusion and perspective

The MECc project can conclude that a Fiat e500-hybrid, which is charged with a methanol fuel cell, is approved and working as a road vehicle at the Danish main roads. User tests conclude that the car should be optimized to fulfil the user demands regarding storage space, acceleration at motorways, and that the infrastructure should be improved with more methanol stations placed in different places in Denmark. The car can also be optimized regarding the charging process, as the battery has not been upgraded, and a 5kW battery has a too small capacity. The MECc concept car has potential in ten different countries in Europe and in Denmark, especially with airport industry, car sharing and public administration, because of green performance criteria, technical opportunities and economic surplus.

In the future, the project can focus on business model development with focus on completing the business model canvas and investigate a green business model with economic potentials. Furthermore, the investigations of the customers can focus on green customers, as it is a customer segment with high focus on investing in green products and improving their green brand.