


Integration of Fuel Cell Range extenders for EV applications Feasibility study

For Aberdeen City Council

January 2017

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Interreg North Sea Region HyTrEc2

European Regional Development Fund

EUROPEAN UNION

Report Content

- Background and project aims
- Summary of activities completed
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  - Power module design
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Background & Project aims

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- The **Symbio Renault Kangoo** has stimulated interest and demand for fuel cell range extension to electric vans
- Their product uses a novel, **French fuel cell stack** technology (5kW) which “trickle” charges the battery to extend the range.
- They incorporate a 74l (1.6kg usable volume) **H2 tank inside the vehicle’s load area reducing space capacity**
- The product has the backing of Renault such that they have confirmed that the **normal warrantees** for the vehicle apply; with the **fuel cell Rx having 2 years (Or 5000 hrs)** alongside it
- We believe that they have **“sold” over 100** across Europe to date; although they are currently on very long lead times for delivery
- The first response after sale support in UK is provided by Arcola Energy; **Symbio provide the technical support**

ULEMCo's Aim for Aberdeen City Council & Partners

- Address the limited range impact
  - When laden
  - Seasonal variation
- Address the impact on load space
- Address the reliability
  - Source a commercially available FC with a proven track record of performance and technical support
- Provide local technical support
- Respond to the immediate project requirements for some vehicles by end March 2018

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Technical Performance Targets

- eNV200 NEDC Range – 106 miles (as per vehicle specification)
- Average miles/hour by a delivery Van – 19.2mph (based on Revolve test fleet)
- Average miles per day by a delivery Van – 153.6 miles/day
- Actual eNV200 Range differs ~15% from NEDC – 90 miles Range
- Fuel Cell should at least improve the range by ~65 miles to meet /day requirement

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Summary of activities completed

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Package Feasibility

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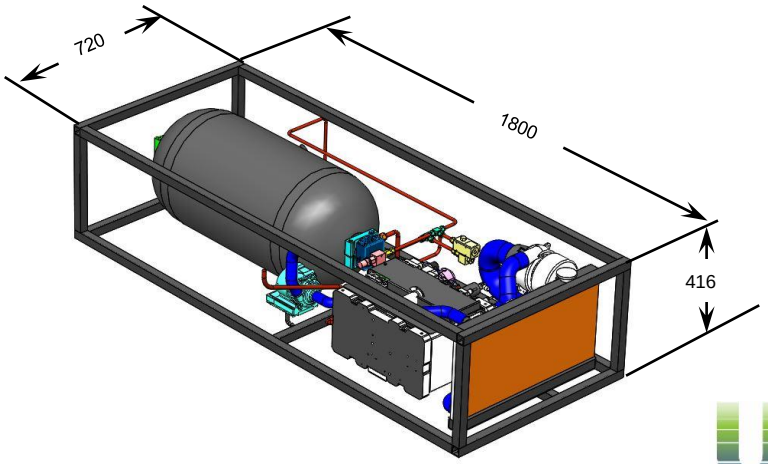
eNV200 Fuel Cell System Package



- Fuel Cell System can be packaged on eNV200 roof *(Additional 450mm added to the base vehicle height: @50mph, Air Friction Force = 29.1 N; which is 0.65kW or 0.87 HP)*
- Mass of ~140kg added to the Roof *(Roof loading is limited by load distribution, by providing additional mounting supports this limitation can be addressed)*
- All hydrogen piping's are hermetically sealed *(potential to route double walled hoses)*
- Modular & Scalable package
- Minimum modification to the base vehicle
- Module can be built offline *(~3 days for conversion & Testing)*
- Easy Serviceability

*** All Dimensions are in mm****

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Project Rooftop
Nissan eNV200 FC Rx™ Conversion

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Vehicle Integration

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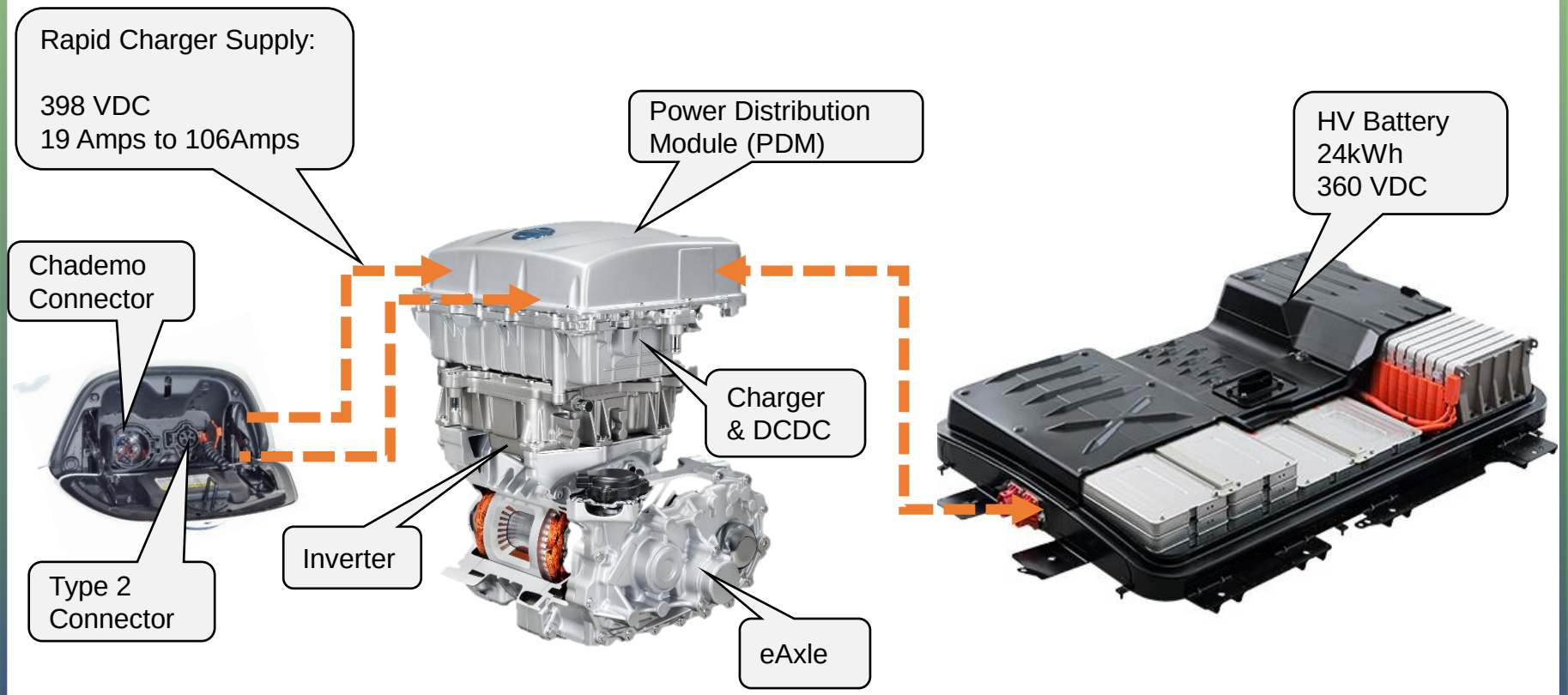
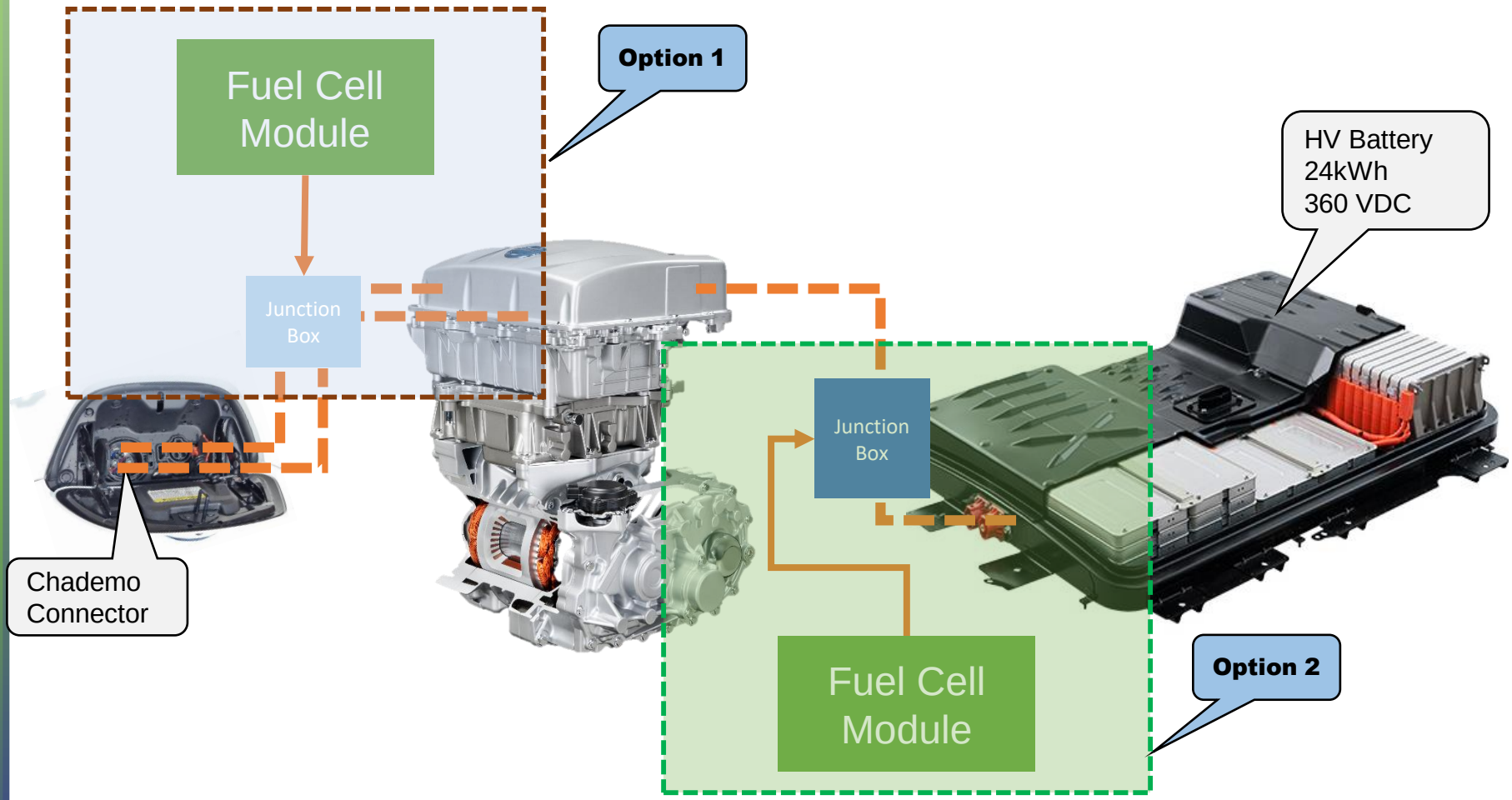
eNV200 HV Layout



Potential Integration Options



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Selected Integration solution

- Introduce a junction box between Power Distribution Module (PDM) & HV Battery
- Supply power through junction box to HV battery

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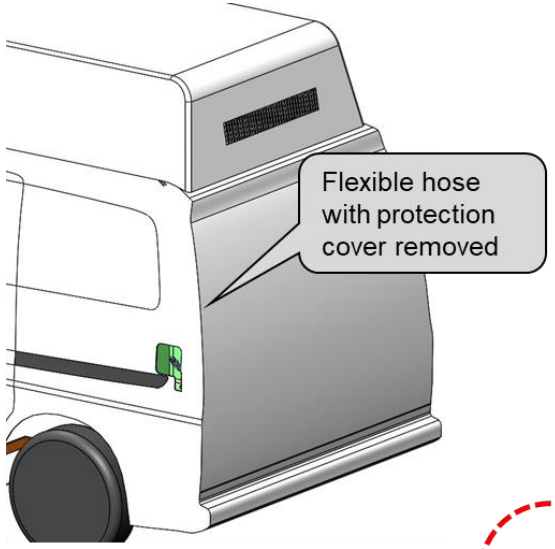
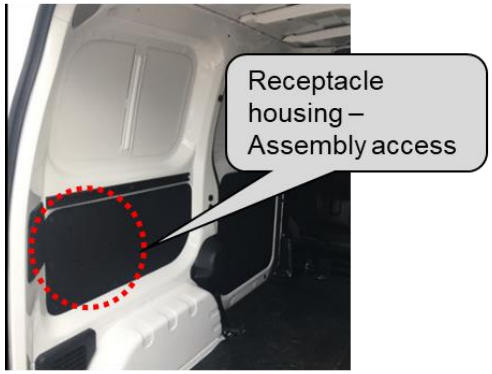
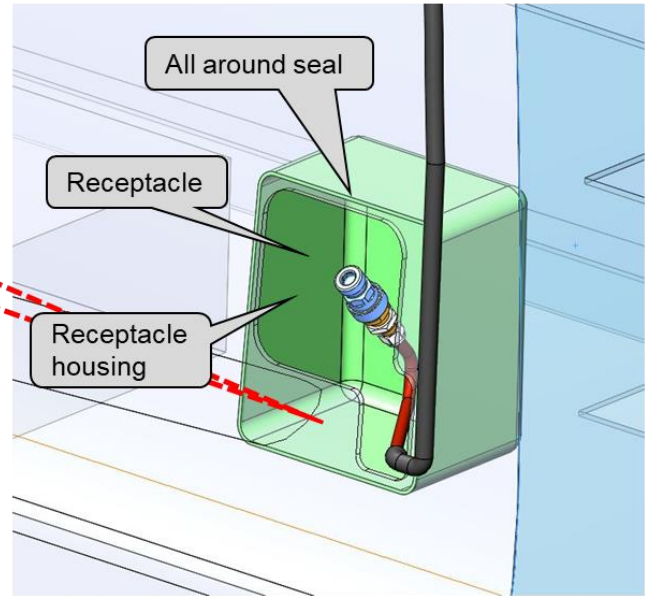
Refuelling System



- ❑ Modification to body side panel
- ❑ Receptacle housing – All around sealed
- ❑ Refuelling flap/door to be added
- ❑ Opportunity for double walled hoses

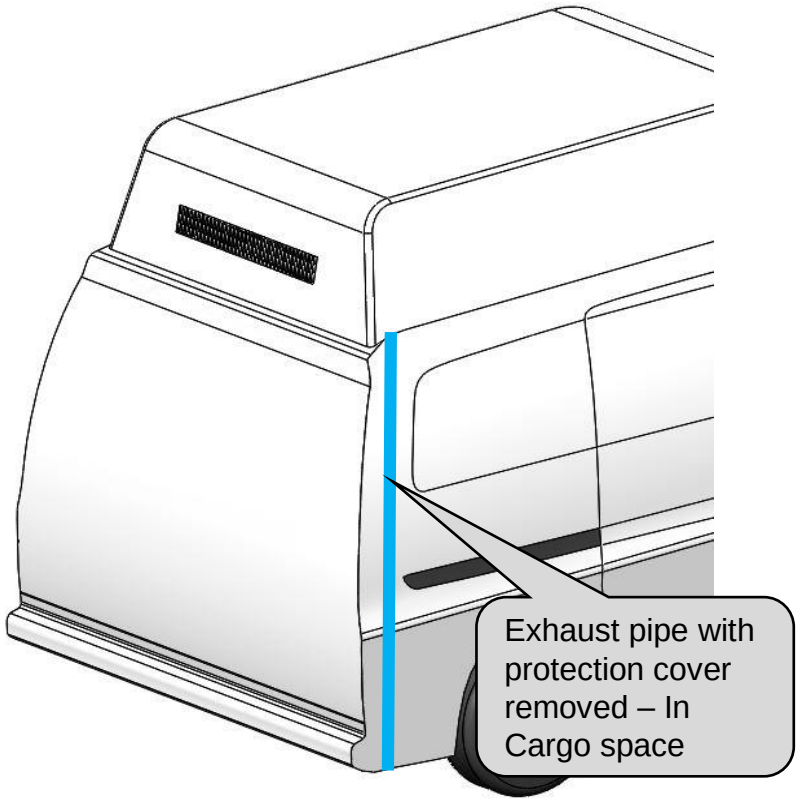


Inside eNV200



Vehicle body shown transparent

Exhaust Piping



- Exhaust (H2O) is piped to the road
- Protection cover over the piping
- Same route will be followed for HV routing

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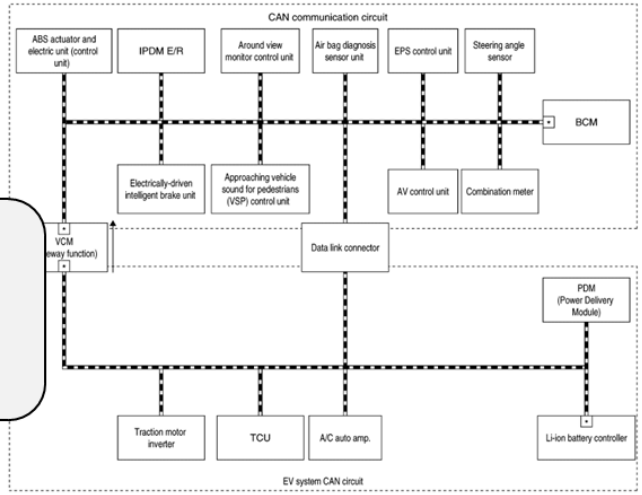
Modified CAN Circuit



eNV200 CAN Circuit

Pedal Demand (PD)

VCM (Main ECU)

Power delivery Module (PDM)

CAN Gateway

Traction Motor Inverter (TMI)

LI-ion Battery Controller (LBC)

Fuel Cell Module (FCM)

CAN Messages Standard
CAN Messages Modified
CAN Messages New

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Power module design

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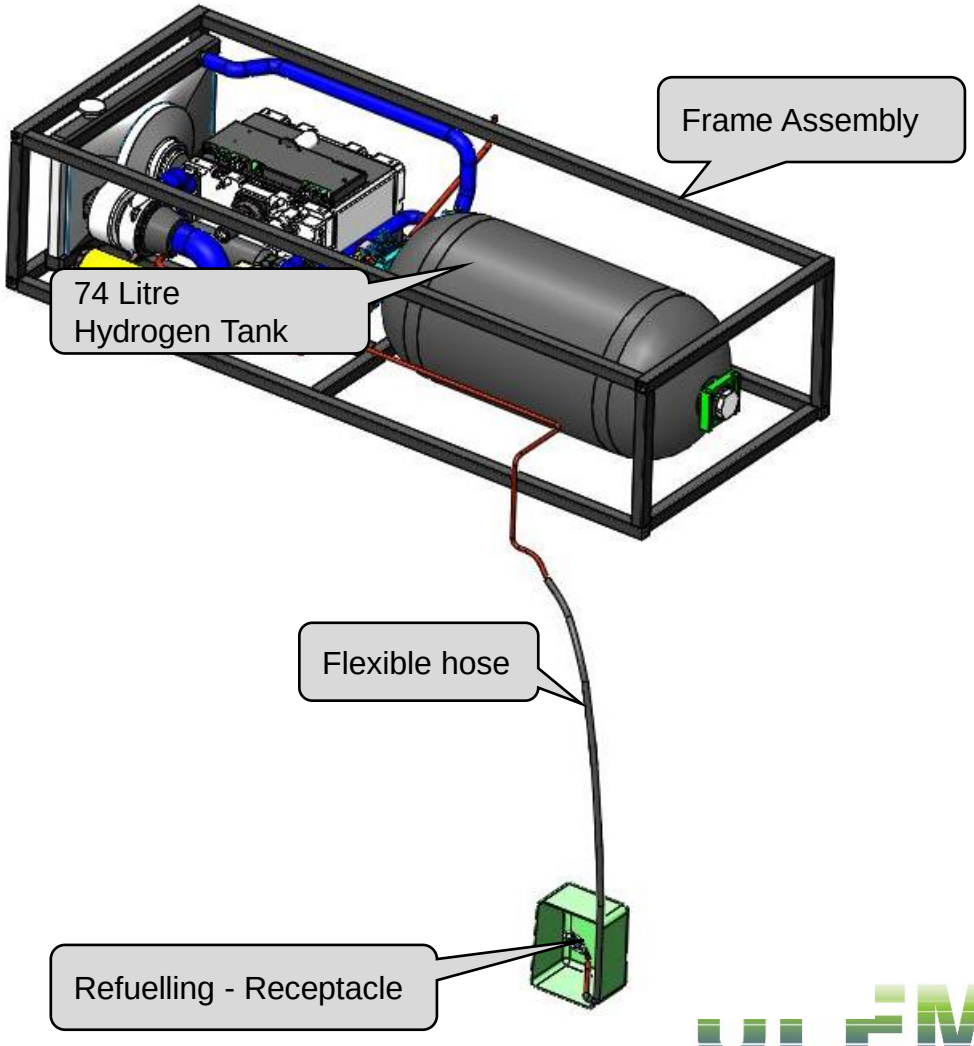
Fuel Cell System Module



- Frame assembly can be mounted on the roof using 6x roof rack mounting points
- Access to additional mounting points, if required
- Additional ingress protection cover on FCell stack
- Additional H tank can be accommodated

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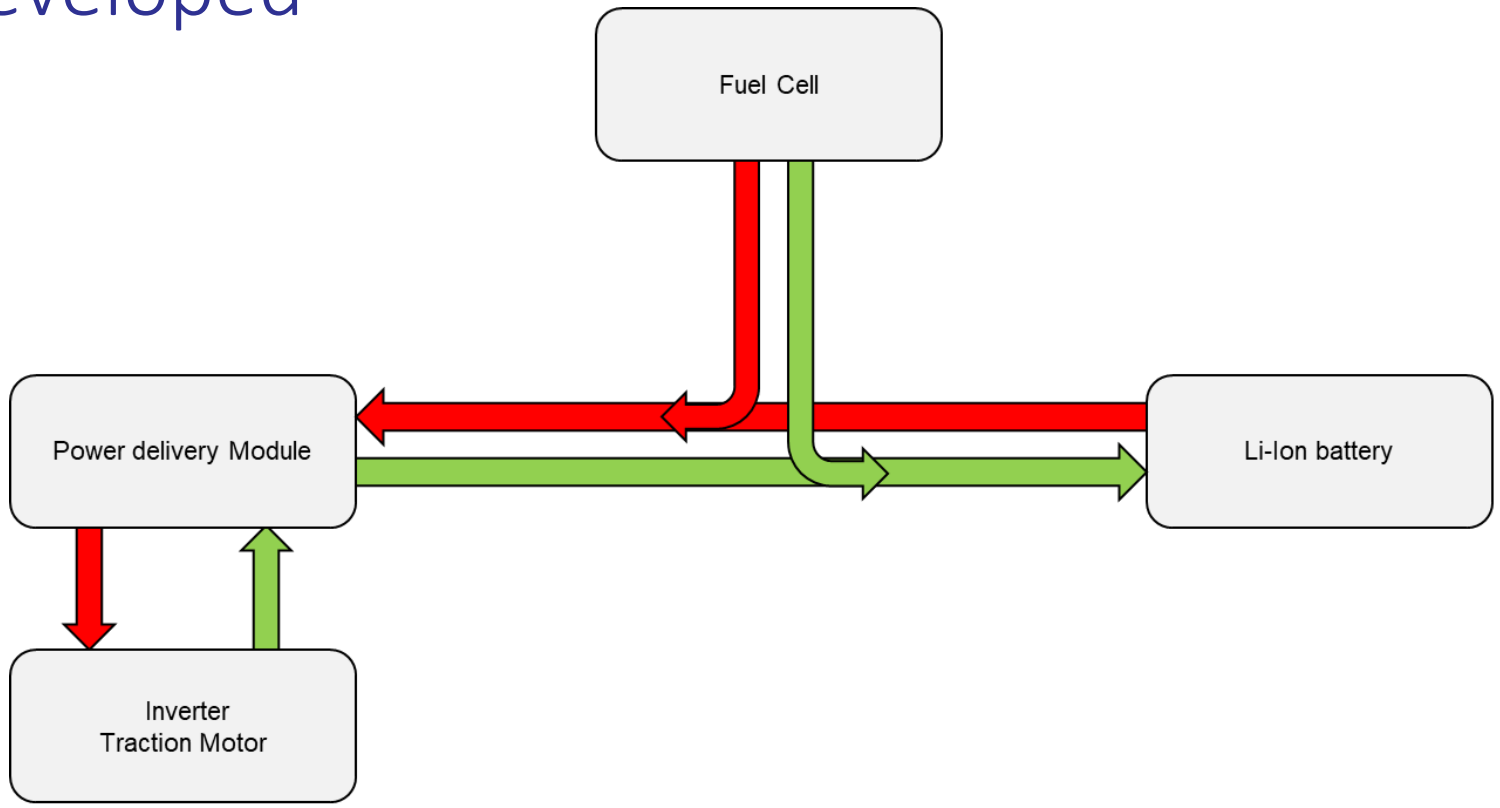
revolve™

ECU energy flows & control strategies developed



Performance Modelling

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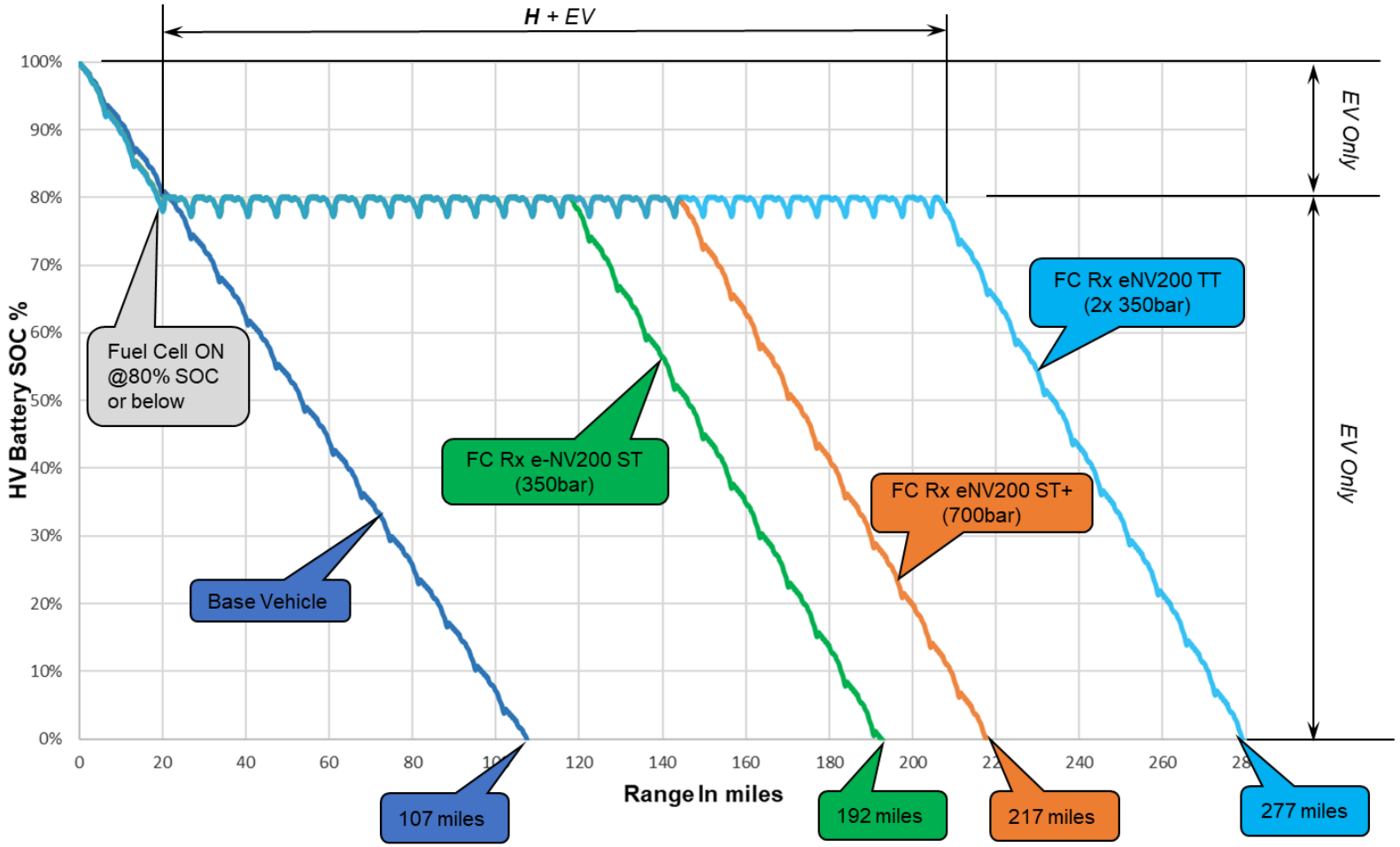
NEDC Drive Cycle with & without Fuel Cell



- *Fuel Cell operation to suit customer requirement*
- *5% H left as reserve*

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Vehicle Specification & Operational capability

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Nissan eNV200 Acenta Rapid

- **Weight**
  GVW – 2220kg
  Payload – 703kg

- **Drivetrain**
  80kW Peak Power & 254Nm Peak Torque
  Single Speed gearbox (1:9.3010)

- **Battery**
  24kWh & 360V L-Ion Battery

- **Charging**
  Type2 - 3.3kW AC on-board Charger
  Chademo Rapid Charge Port (Allowing 50kW DC)

- **Estimated Range**
  106 miles (NEDC)

- **Overall Dimensions**
  4650(L)x 2011(W) x 1858(H)

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Headline Specification of FC Rx e-NV200

	eNV200	FC Rx e-NV200 ST	FC Rx e-NV200 ST+	FC Rx e-NV200 TT	Remarks
Tank Pressure	N/A	350bar	700bar	350bar	*2x 350bar tanks used in FC Rx e-NV200 TT*
Range	106 miles	192miles	217 miles	277 miles	*Can be further increased by adding additional tank*
Payload	703kg	563kg	542kg	523Kg	*Average fleet Payload is 350kg*
Cargo Capacity	4.3m3	4.3m3	4.3m3	4.3m3	*Fuel Cell Module is roof mounted*
Vehicle Height	1858mm	2308mm	2308mm	2308mm	*450mm Over base Vehicle*

Fuel Cell Operation

- User interface will allow to select priority
  - Fuel Cell Mode
  - EV only Mode
  - Static Charging Mode (@ Peak Efficiency)
- Fuel Cell will be ON only when HV battery SOC is 80% or below except on Static charging Mode
- Opportunity to use Fuel Cell as a power source for running Ancillary equipment's (110AC & 230AC) - @Peak Efficiency
- Opportunity for Smart Vehicle System (longer term)
  - Define route plan
  - Define load plan
  - System will decide and operate in the most efficient mode (Refuelling point, Recharging point, cost of H, cost of electricity, etc.)

Project learning to date

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Packaging learning

- Roof top is feasible within additional weight, aerodynamic impacts and stability constraints
- The above allows for a power module that could be refitted onto future vehicles
- The integration of the above has minimal impact on the base vehicle which mitigates against residual value
- The integration of the above also allows for off vehicle manufacturing which minimises the time the base vehicle is needed for fitting
- This solution also minuses labour cost for the vehicle integration step
- This adds 500mm on height so will have some application limitations where height restrictions apply

Learning from power module design

- The design allows for space for additional tanks and or alternative 700 bar solutions
- There is space for larger fuel cell units if more fuel cell power is desired
- The fuel cell supplier has significant experience and performance data that both helped integration and will provide the customer with a reliable solution

Learning from the modelling

- NEDC drive cycle used for range prediction
- Modelling helped to decide size of the fuel cell required and hydrogen storage to meet range and operation requirements
- This further helped to optimise hydrogen and electric usage depending on operator preference and fuel cost
- Modelling used to understand the impact caused to vehicle the vehicle performance by introducing additional mass, installation location etc.

Learning on the vehicle integration

- Open source CAN database assisted the process
- Supplied 400VDC to the Nissan eNV200 High Voltage (HV) DC bus by using an external power source and found no error flags
- Vehicle accepts external power as Regen to charge the battery and also uses when there is a demand
- This proves when the vehicle is operational the power demand will be shared between Fuel Cell & HV Battery without any modification to the base vehicle operation strategy

Learning on the BOM

- Long lead time items include:
  - Tanks – 12 weeks imported from Canada and require upfront payment
  - Fuel Cell – 12 weeks from Germany & require upfront payment
  - Pressure regulators – limited supplier choices with EC79 approval
- DC/DC converter

- Tank price drops if batches can be procured (200 off)
- FC cost drops by x% if over x can be procured
- DC/DC step change at x volume

- Shortage overall in EC 79 approved suppliers for high pressure components
- Other parts are fairly standard for auto sector

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Next steps

- Order BOM components
- Complete design of Roof top box and other bespoke parts
- Build Prototype Power module
- Integrate onto vehicle
- Test and Commission
- Gain Type approval or equivalent
- Deliver to customer
- First fill test & driver training
- Gather use data
- Report on results of trial use period

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