Electric Vehicle

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산업 환경 변화

전기차 시장 확대 배경

- 2015년 파리 기후 협약(195개국)

  - 자연 재해 방지를 위해 탄소가스 배출 억제를 통해

    지구 연평균 온도상승을 산업 혁명 이전 보다 2℃이내로 억제하자

    → 국가별 탄소가스배출 제한 → 전기차 증

EU 내 완성차 판매기업은 평균 판매대수를 기준으로 대당 연평균 CO^2 배출량이 2015년 130g/km, 2020년 95g/km을 상회하지 않아야 함

- VW diesel Gate

  - 배출가스 저감 장치 조작 program: 디젤 엔진의 한계 확인, 전기차로 전략 변경

- 세계 시장 변화

  - 독일, 인도, 2030년, 프랑스, 영구 2040부터 배출 차량 판매 금지 발표

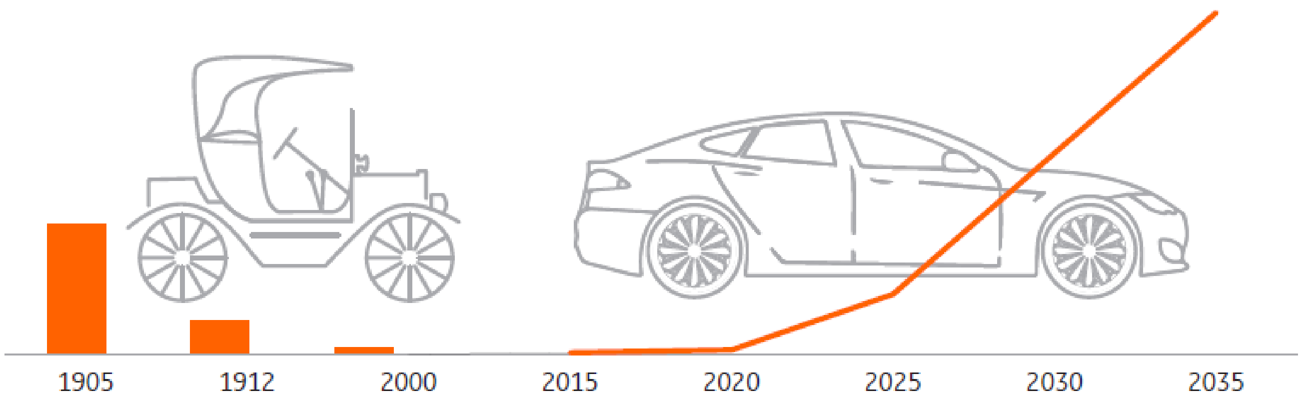
"대신 증권 리서치 기업분석 2017"

Electrification

Electrification isn't new for the industry

At the turn of the 20th century, electric cars accounted for 38% of US registrations. But their share soon declined. Sales peaked in 1912 in the US at 6,000. By contrast, in that same year over 80,000 Ford Model T's, with an internal combustion engine, were sold. In 1912 an average petrol car cost $ 650 vs. $ 1,750 for an average electric car. Today, after more than a century, electric cars are back and ready to stay.

Historic and forecast market share trend of BEVs



Source: IEEE, The rise and fall of electric vehicles in 1828-1930 - lessons learned, C.C. Chan.

Powertrain	Components that generate power and deliver it to the road
ICE	Internal combustion engine vehicle, operating on fuel.
HEV	Hybrid electric vehicle. Operates on internal combustion engine, assisted by a battery (charged by braking energy). Short distances on battery alone.
PHEV	Plug-in hybrid electric vehicle. Also combines ICE with battery power, but can be charged (plugged in to grid) to drive 30-60 km's on its battery.
BEV	Battery electric vehicle, fully operating on battery electric power.

IC Engines

주요 자동차 업계 **전기차 전환 계획**

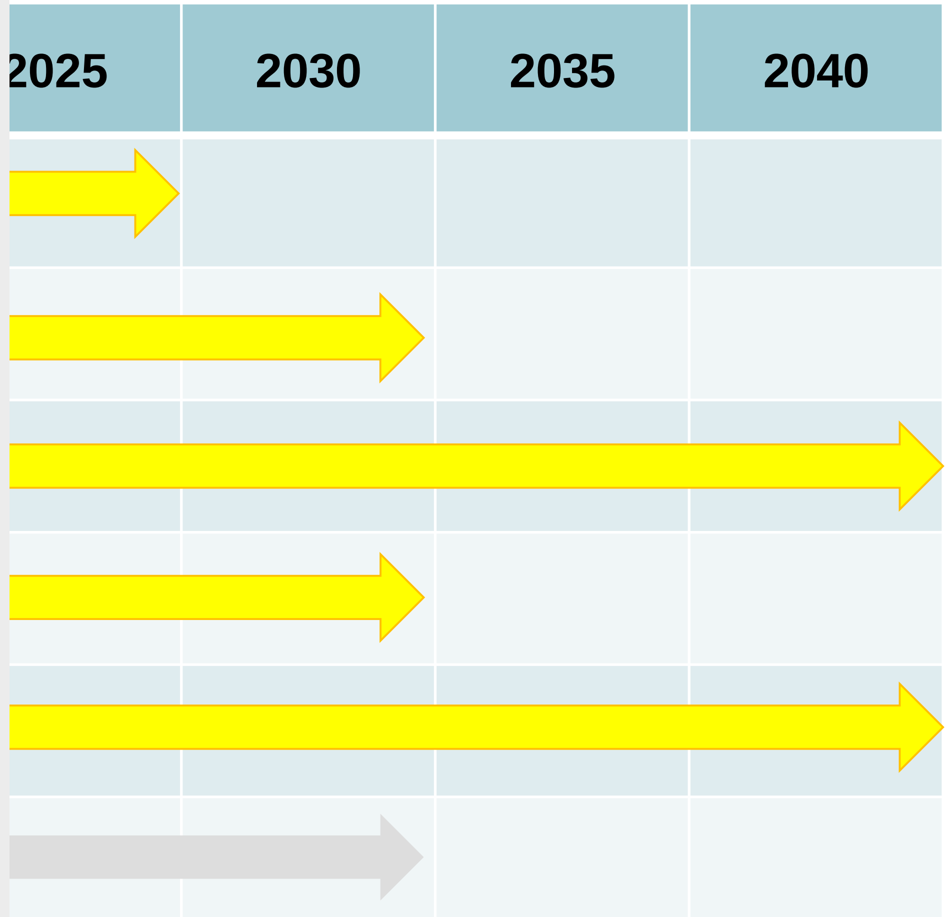
현대	2035년부터 유럽에서 전기차만 판매 2040년까지 미국·한국 등 주요 시장에서 순차적으로 모든 판매 차량 전동화 완료, 전기차 판매 비중 80% 목표
GENESIS 제네시스	2025년부터 모든 신차 수소·배터리 전기차로 출시 2030년 친환경차 40만대 판매 목표
GM	2025년까지 전기차 30종 출시, 향후 5년간 R&D 270억달러 투입 2030년 캐딜락 전체 생산 모델 전기차 전환 2035년 이후 휘발유·디젤 엔진차 생산 판매 중단
벤츠	2030년부터 전 차종 전기차 출시, 배터리 전기차 부문에 400억유로 투자
볼보	2024년까지 글로벌 판매 50% 전기차, 50% 하이브리드 차로 구성 2030년까지 전체 생산 모델 전기차 전환
폭스바겐	2029년까지 전기차 75종 출시 2030년까지 신차의 절반 전기차로 판매 2035년까지 유럽에서 내연기관차 판매 중단
BMW	2030년까지 순수 전기차 1천만대 공급
포드	2030년부터 유럽에서 전기차만 판매
HONDA 혼다	2030년까지 전기·연료전지차 20%, 하이브리드차 80% 2040년까지 전기차·연료전지차만 판매

자료/각사

연합뉴스

이경아 인턴 / 20210907

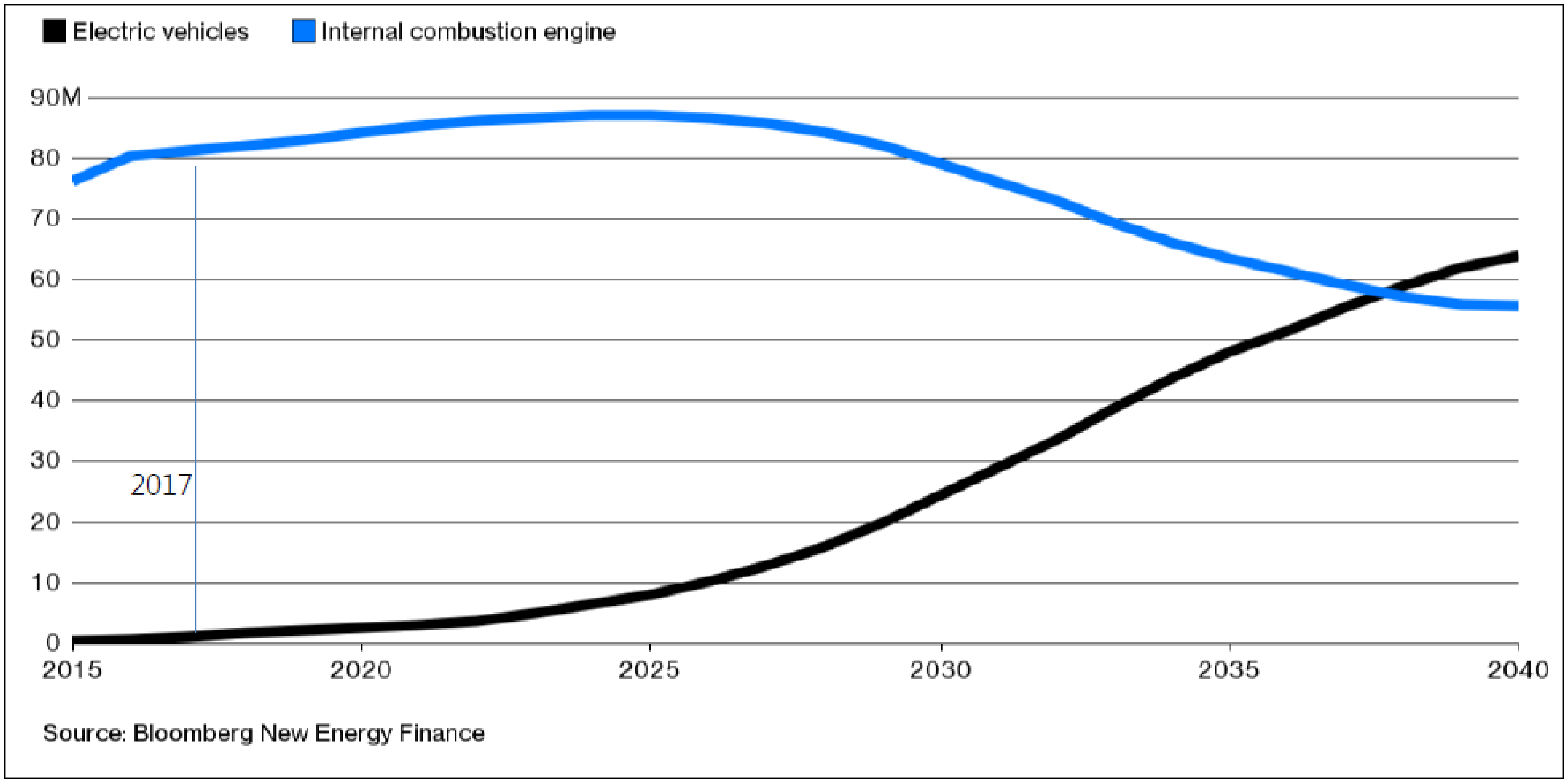
트위터 @yonhap_graphics 페이스북 tuney.kr/LeYN1



Global Market Forecast

xEV 시장 점유율 예측

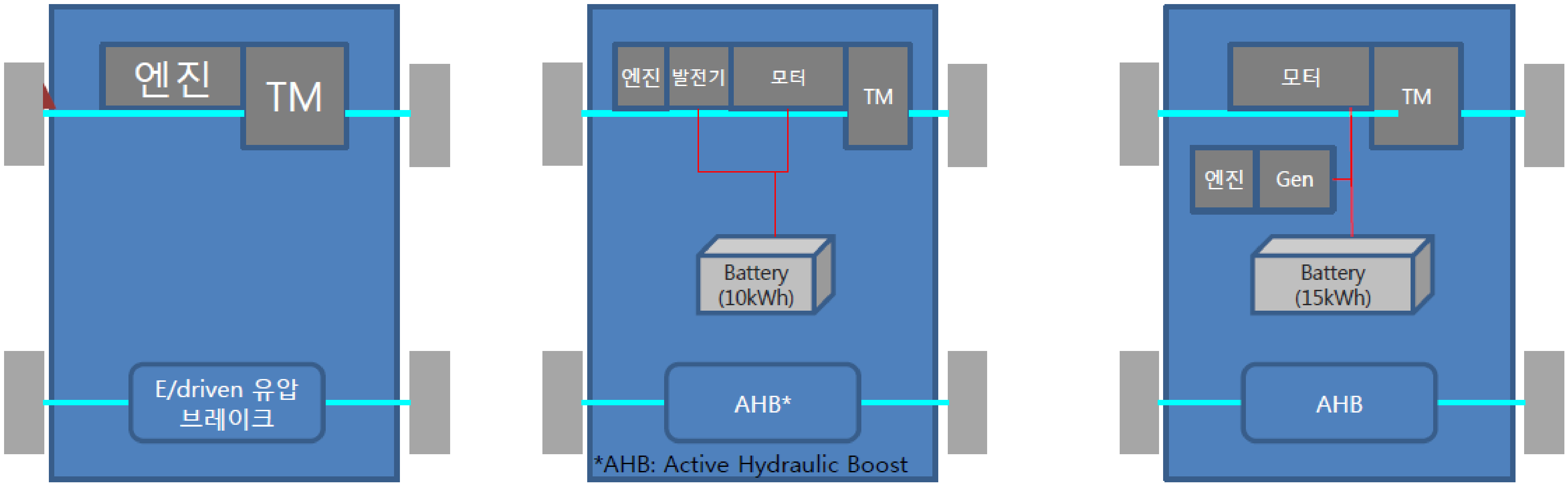
전기차와 내연기관 차량 댓 수 예측(Bloomberg, july 2017)



전기차의 수량은 증가하나 **내연기관** 차량의 댓수는 완만히 감소

← 충전 infra, 차량 가격(Battery 가격), 운전 비용 등이 주요 영향인자

xEV 구분



순수엔진 자동차

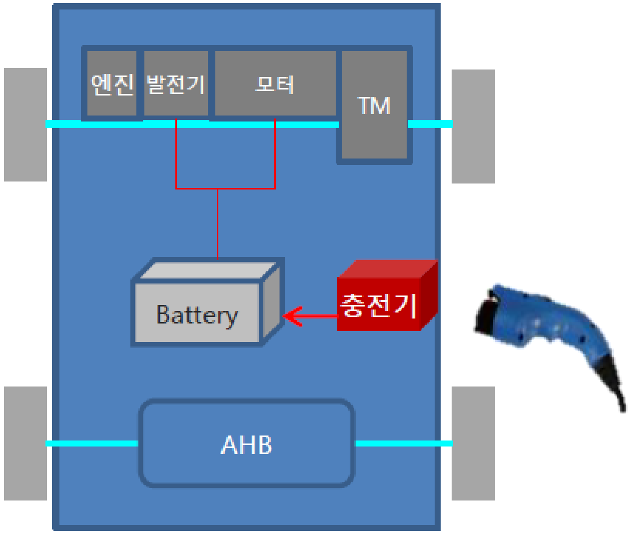
Parallel HEV(Honda Insight, T Prius)
(병열 Hybrid Electric Vehicle)

Series HEV
(쉐보레 Volt, BMW i3)

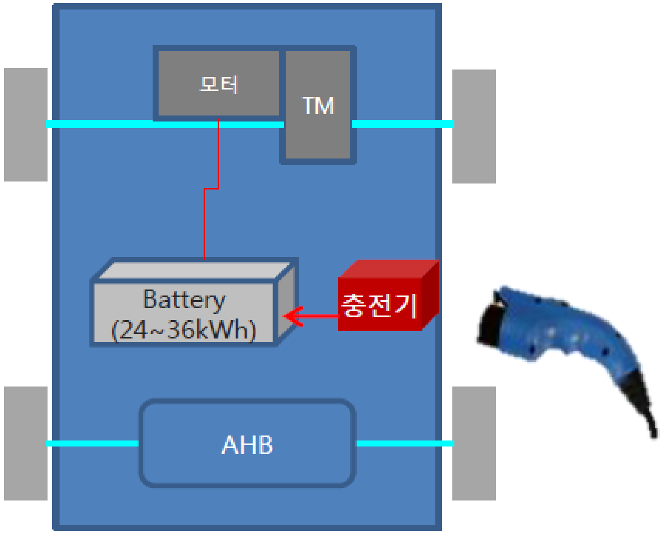
회생제동(Regenerative Braking) : 주행 중 브레이크를 밟았을 때 배터리를 충전해주는 기능으로써 하이브리드차 및 전기차에서 유용하다.
이 기능 구현에 중요한 역할을 ***'능동형 전자제어 브레이크(AHB)'***가 담당하고 있는데, 이 AHB는 회생제동 이외에도 브레이크 잠김 방지장치(ABS), 구동력 제어시스템(TCS), 전자제어 주행안전장치(ESC)등의 기능을 탑재한 통합형 제동장치이다.

xEV 구분

2017년 말, 국가기술표준원에서
전기차 DC콤보 1으로 급속 충전 표준 통일



PHEV
(Plug-in Hybrid Electric Vehicle)



BEV

배터리 용량이 가장 큰 전기차 종류는 ?

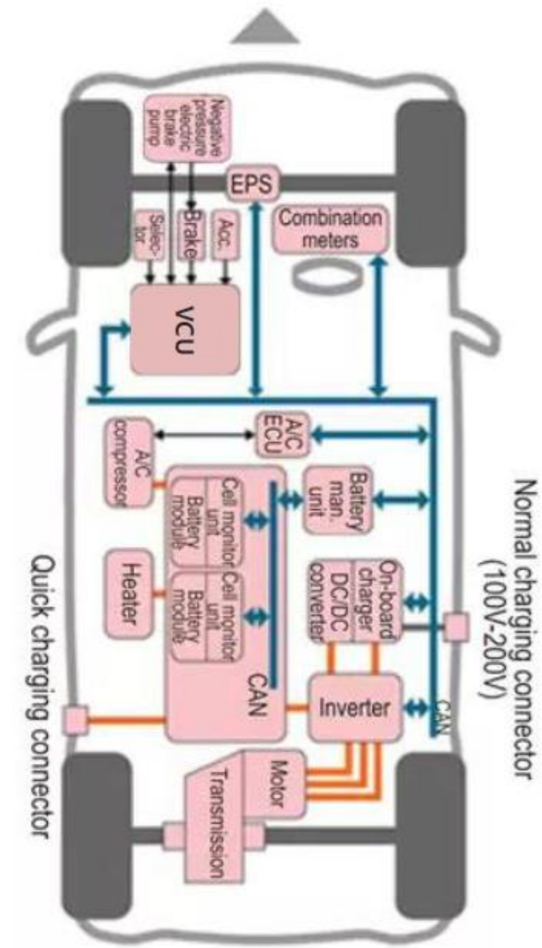
전기차 부품

II. 구성

1) 전기에너지원
2) 구동 시스템(Motor+ G/box)
3) 전기 발열, 냉방
4) 차량 운동 제어장치(VCU)
5) 에너지 현황 표시장치
6) 전기 interface 장치
7) 전기차용 브레이크
8) 냉각 장치
9) 모니터링 장치(BMS등)
10) 전력 변환

http://www.fleetsandfuels.com

구성 부품

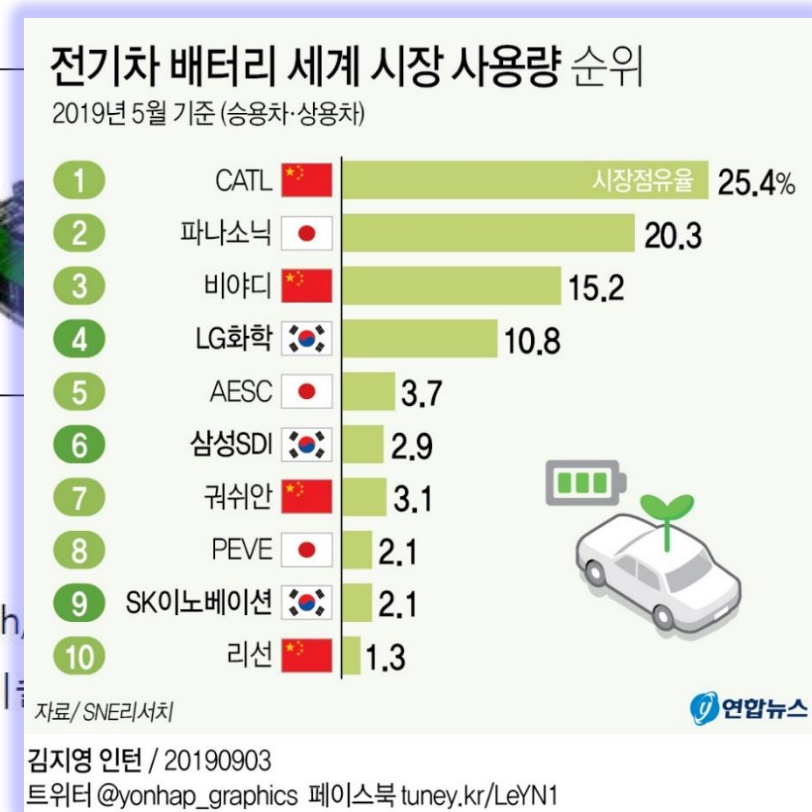


연결도

전기 에너지원

1) Battery : 초기 도요타 프리우스에 NiMH battery가 쓰였으나,
현재는 리튬 이온 배터리가 가장 많이 쓰임.

2) 구조



3) 발전 방향

- 가격 절감 기술: ($273 → $72/kWh)
- 충전 밀도 증대 기술(250wh/kg, 650wh/l → 500wh,
- 충전 시간 단축위해 급속 충전 전류량을 늘리는 기

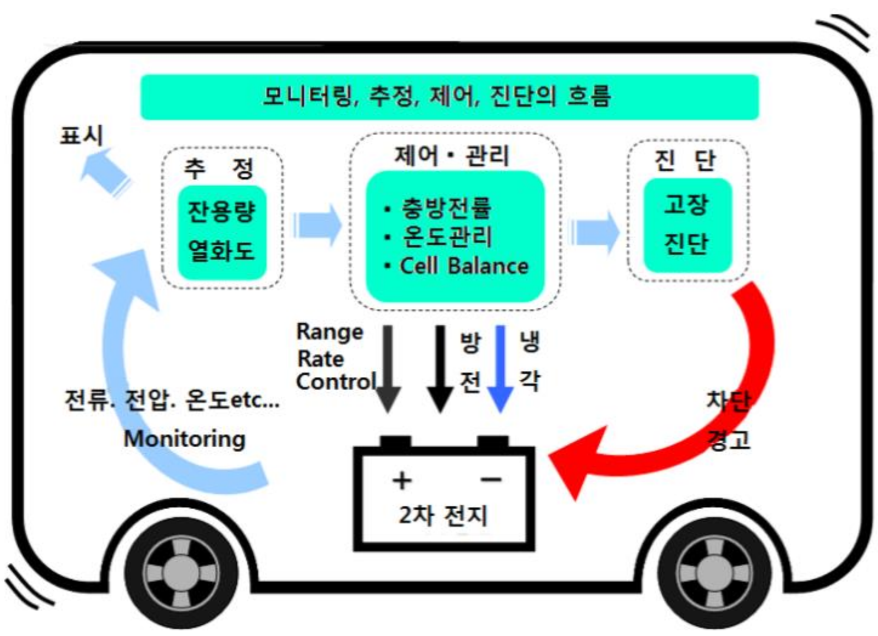
BMS

배터리 관리 시스템(BMS)이란?

- 배터리 관리 시스템(BMS)은 배터리를 최적으로 관리하여 에너지 효율을 높이고 수명을 연장해주는 역할
- 배터리의 전압, 전류와 온도를 실시간으로 모니터링하여 과도한 충전 또는 방전을 미연에 방지하고 배터리의 안전성과 신뢰성을 향상시킴
- 전동화자동차의 주행거리 증가를 위해 배터리 관리시스템의 중요성 증대

BMS의 핵심 역할

- 에너지 효율을 높이고 배터리의 수명을 연장
- 셀 밸런싱 기능을 통해 배터리의 최대 에너지를 최적화하여 사용할 수 있도록 관리
- 배터리의 냉각 장치(냉각 블로워, 냉각유로)를 제어하여 배터리 열을 관리하는 역할을 하는데 이로서 배터리 시스템이 최적의 수명을 유지



모터와 인버터

❖ 전기자동차의 구동모터와 인버터는 배터리의 전력을 이용하여 구동력을 발생시키는 동력원으로서, 내연기관차의 엔진에 대응

❖ 구동모터와 인버터의 기술발전 방향은 '2高-2低' 로 요약될 수 있음

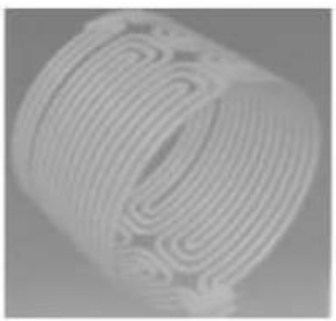
❖ 구동모터와 인버터의 '2高-2低' 실현을 위해,

- 구동모터의 구조(Motor Type) 개발, 냉각기술(Cooling)의 개선, 자기회로 최적화, 회전속도의 증대 등을 전개하고,
- 인버터의 냉각기술 개선, 차세대 파워소자의 적용을 추진

모터와 인버터

❖ 고효율, 고출력밀도, 저NVH, 저가격의 방향성을 달성하기 위하여, 수냉식의 영구자석형 모터와 파워모듈을 채용한 인버터를 상용화

모터



- 영구자석 채용을 통한 고효율화
- 하우징 수냉을 통한 고출력밀도화
- 헤어핀권선 등 새로운 기술 채용
- 영구자석을 사용하지 않는 구조 시도

인버터

- 수냉 방식의 자동차용 파워모듈 채용
- 내구성 면에서 필름 커패시터를 채용
- 400Hz급의 고주파수 전력변환
- 차세대 전력반도체(SiC) 적용 시도

모터와 인버터

❖ **파워 소자의 혁신을 통해 혁신적 고효율/고밀도화 구현**

➢ 이중냉각 구조 등의 고성능 냉각기술 개발과 SiC 차세대 반도체 소자/모듈의 적용을 통한 인버터의 성능 향상

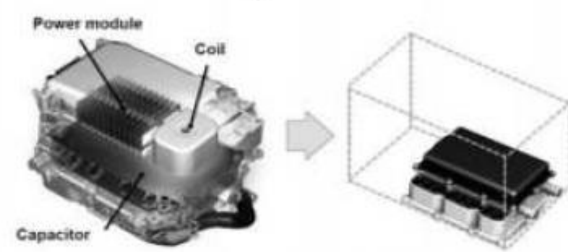
과거 → 현재

Si-모듈 기반 인버터
(출력밀도 11kW/L)

Double-Sided 고밀도 냉각
(출력밀도 14kW/L)

미래

SiC 파워모듈 적용연구
고밀도/고신뢰성 회로설계기술 연구



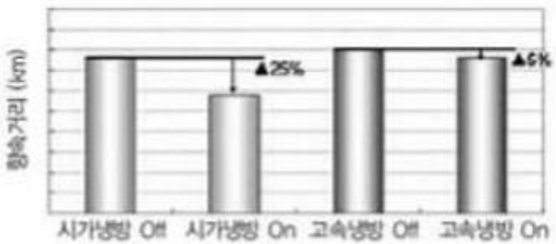
SiC 탑재 고밀도/고신뢰성 인버터
(Toyota, 출력밀도 30kW/L)

공조 및 열관리 시스템

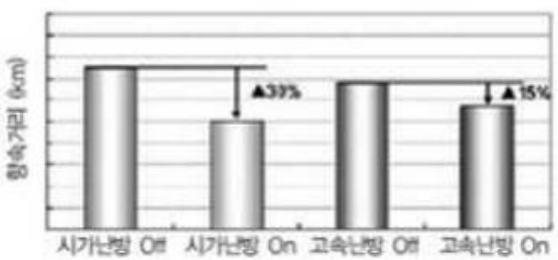
❖ 전기자동차 공조시스템 장치 개발의 필요성

- ➢ 전열 장치를 통한 온도 관리 시 30~50% 주행거리 감소로 전기자동차 보급에 부정적 영향
  - • 적정온도 유지를 위해 소모되는 에너지를 줄여 주행거리 개선하는 기술개발 진행

냉방 및 난방 장치 가동 시 주행거리에 미치는 영향



(a) 냉방장치 사용시 주행거리



(b) 난방장치 사용시 주행거리

전기자동차의 냉방 및 난방 시스템 개발 현황

메이커		Mitsubishi	Nissan	Tesla	Ford
모델		I-MEV	Leaf	S-Model	Focus BEV
사진					
공조	냉방	전동 압축기	전동 압축기	전동 압축기	전동 압축기
	난방	전기히터 (냉각수)	전기히터 (냉각수)	전기히터 (공기)	전기히터 (냉각수)
	제어	Manual	Auto	Auto	Auto

분류	히트펌프 시스템	배터리 통합 열관리 시스템	국부 냉난방 시스템
주요 품목 및 기술	히트펌프 시스템 기술, 통합 열관리 시스템 기술, 열관리 제어기술, 저온 운전 기술, 압축기 제조 기술, 열교환기류(증발기, 응축기, 칠러) 제조 기술, 전동식 밸브류 제조 기술, 전기히터 기술 등		
해외기업	Toyota(일본), Valeo(프랑스), Mahle(독일), Kansai Calsonic(일본), Catem(독일)	Toyota(일본), Valeo(프랑스), Mahle(독일), Kansai Calsonic(일본), Catem(독일)	Toyota(일본), Valeo(프랑스), Mahle(독일), Kansai Calsonic(일본),
국내기업	한온시스템, 두원공조, 갑을오토텍, 대한칼소닉, 동환산업, 이래오토모티브, 우리산업, 동아전장	한온시스템, 두원공조, 갑을오토텍, 대한칼소닉, 동환산업, 이래오토모티브, 우리산업, 동아전장, 영화공업	한온시스템, 두원공조, 갑을오토텍, 대한칼소닉, 동환산업, 이래오토모티브

자료 : 중소·중견기업 기술로드맵(2017~2019)

공조 및 열관리 시스템

❖ **주행거리 증대를 위한 고효율 공조 시스템**

- 기존 난방 시스템(전기히터) 보다 효율이 높고 친환경적인 히트펌프나 PTC 히터를 활용하여 냉난방 시 주행거리 감소를 최소화한 공조 시스템이 개발 진행 중

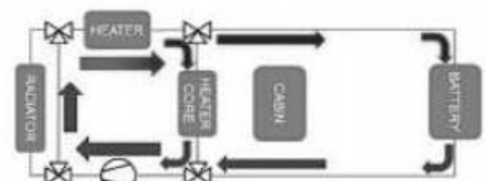
❖ **파워트레인 효율 및 배터리 수명 증대를 위한 통합 열관리 시스템**

- 배터리 온도 유지 및 모터, 인버터의 냉각 뿐만 아니라 실내 공조 시스템과도 통합된 고효율 통합 열관리 시스템

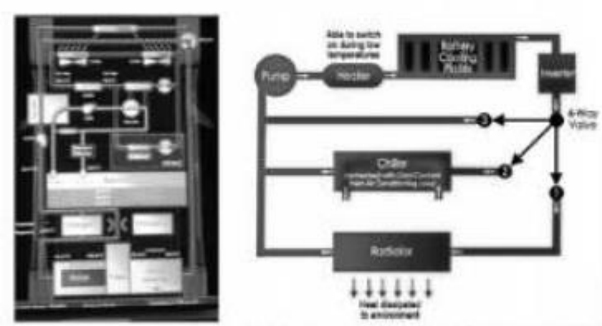
전기차용 히트펌프 시스템 적용 현황

		Mitsubishi I-MiEV	Nissan Leaf 13 My	Renault ZDE(SM3 EV)	BMW i3	Toyota iQ EV
사진						
냉방		전동 Comp.	전동 Comp.	전동 Comp.	전동 Comp.	전동 Comp.
난방		가열식 고전압PTC히터	H/PUMP시스템 +공기가열식 고전압 PTC HTR	H/PUMP시스템 +공기가열식 고전압 PTC HTR	H/PUMP시스템 +공기가열식 고전압 PTC HTR	H/PUMP시스템 +공기가열식 고전압 PTC HTR
	H/P 작동 온도	N/A	- 10℃ 이상	N/A	N/A	- 10℃ 이상
	제상	N/A	Hot Gas 이용	N/A	N/A	Hot Gas 이용

전기차용 통합 열관리 시스템 예시



[실내 난방 및 배터리 열관리 통합 시스템 (예시)]



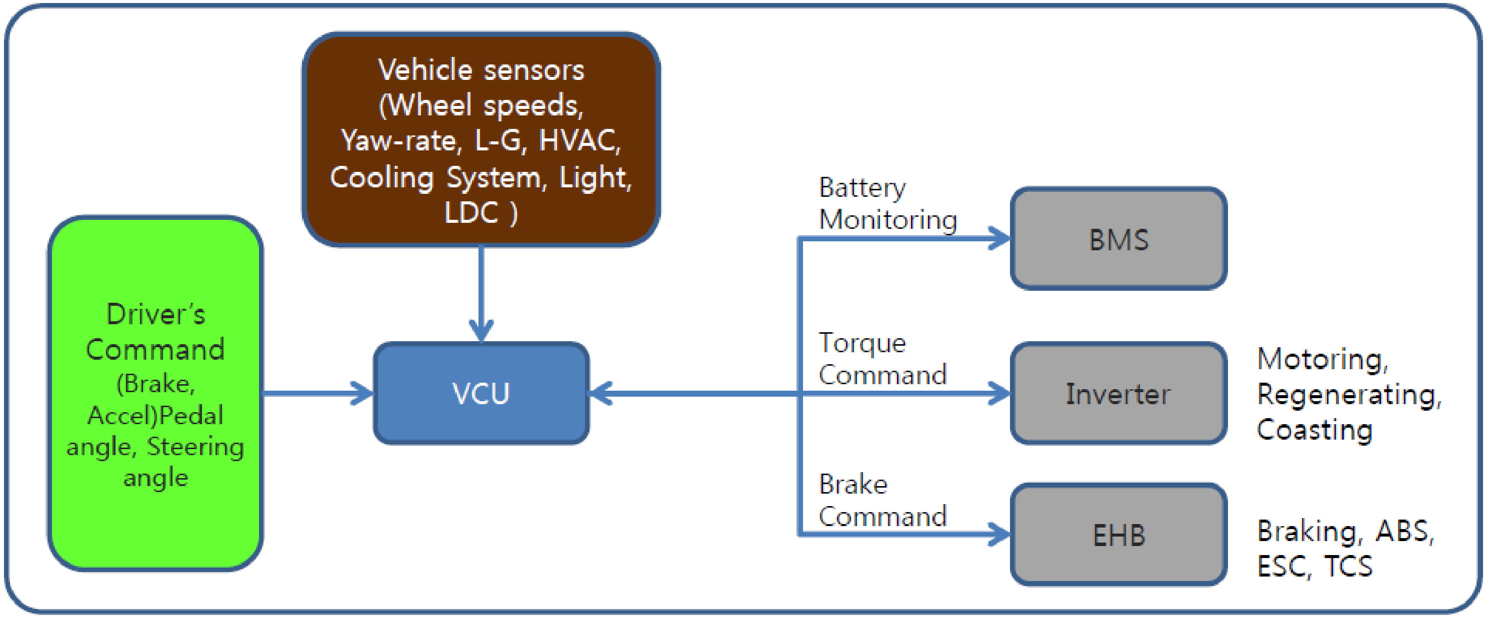
[전기자동차 열관리 융합 시스템 개발 (예시)]

VCU

1) 전체 차량을 제어(관리)하는 장치

2) 냉각, horn, 전등, Drive by wire, riding modes, regen modes, safety and diagnostics, data-logging 등 차량의 모든 에너지 사용과 regeneration을 monitoring서 battery의 성능을 최대로 내도록 관리함

3) VCU 기능 예제(Accelerating, Braking)



에너지 상태표시 UI

1) Battery 충전 잔량, 가능 주행 거리, 충전소 와 거리 등 표시 하는 장치

2) 예: Tesla 의 경우 Steering wheel 뒤의 display는 실시간으로 차량의 상태를 표시하고,

센터페시아의 Display는 운전자의 차량 제어(Door lock, Drive mode 등) 입력 장치로 사용 되고 있으며,

기존의 AVN 기능을 포함한다.

3) 향후 방향

- ISO26262를 만족하는 SW (운전자기 안전의 영향성에 따라 불량율이 낮도록 설계)
- 운전자의 조작성 까지 ISO26262 규정 준수요구 가능

전기 인터페이스

1) 전기적 연결을 위한 connector

2) 기존 차량 사용 전압, 전류 대비 크고, 국제 규격

3) 예:

< 전기차 충전 3가지 방식>

구 분	 차데모	 DC콤보	 AC 3상
개발 시기·주체	'10년 도쿄 전력	'11.10월 GM등 독일, 미국의 7개 기업	'12.12월 르노
적용기업	닛산, 도요타, 미쯔비시	GM, BMW, Ford, 폭스바겐	르노
국내적용차	기아 레이EV, 소울EV	GM 스파크 EV, BMW i3	르노삼성 SM3 Z.E
특 징	- 완속·급속 소켓이 구분 - 전파 간섭의 우려가 적음	- 충전구가 하나로 효율적 (완속·급속이 위아래로 위치) - 비상급속 충전이 가능 (15분 소요)	- 배터리와 전력망을 전기 교란으로부터 보호하는 기술(갈바닉) 적용
단 점	- 충전기 부피가 큼 - 충전시간 다소 김 (80% 충전하는데 30분 소요)	- 급속충전시간에 비해 완속 충전 시간이 김	- 충전기 출력을 20kW 이상 올리기 어려움 - 충전기 설치비용 높음

4) 신기술 동향

- 급속 충전시 전류 양이 증대되어 (Tesla Model S, 60kWh battery 300V에 50% 충전시 200A 30분, 3분 충전을 할 경우 2,000A 충전 필요) 고전류 connector 기술 개발 중

- 전동기차에 적용 중인 (pantograph) 충전 등 개발 중

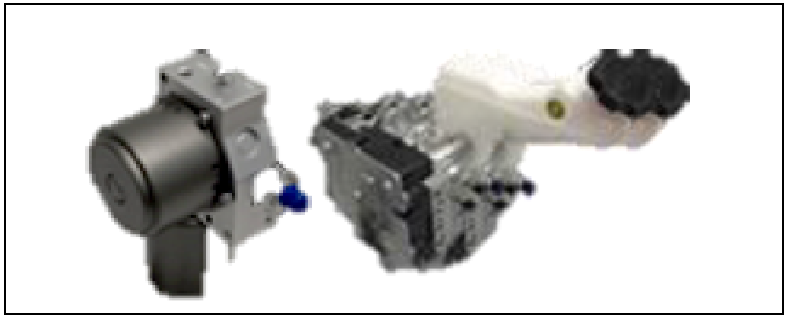
전기차용 Brake

1) 전기차가 운전자의 의도로 감속시, 모터의 regeneration brake량과 조합하여 자연스런 braking을 할 수 있는 장치

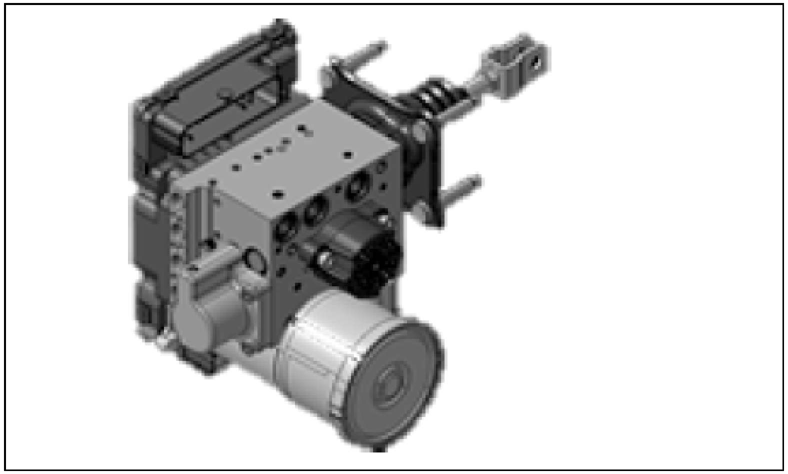
2) 기존의 엔진에서 얻을수 있는 braking boost 압력을 모터구동 유압 펌프로 부터 얻어 제동함

3) 예 : 만도 EHB, 만도 IDB(Integrated Dynamic Brake)

전기차에서 스스로 에너지를 생산할 수 있는 유일한 장치



기존 진공 부스터를 대신하여 필요한 압력을 생성해주는 별도 고압장치와 ABS/ESC가 통합된 Brake Actuation Unit으로 구성되어있음

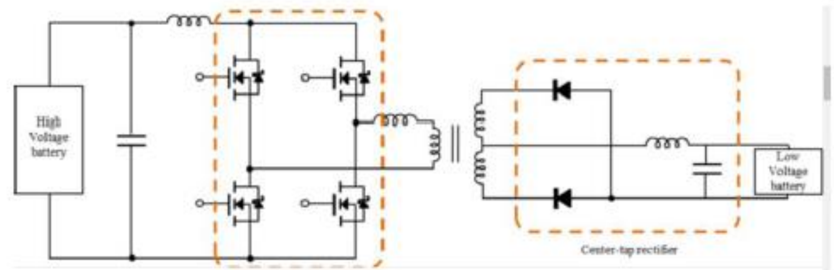


모터로 직접 압력 피스톤을 구동하여 제동 압력을 생성하는 통합형 전자 브레이크로서 기존 진공부스터를 대체하고 ESC의 모든 기능을 포함하는 일체형 통합 브레이크 장치

전력변환장치(LDC)

1) LDC : 250~350VDC를 12V로 바꾸는 전력 변환 장치

2) 예:



3) 기술방향

- 전력 밀도 증대, inverter 또는 OBC와 결합

- 전력 변환주파수 증대로 소형화(200kHz → 1MHz)

: 고주파수 구현시, 기생 성분에의한 이상 동작, 재료 특성 이해와 특성에 순응하는 설계

전력변환장치(OBC)

1) OBC(On board Battery charger): 외부 전력으로 차량 내의 고전압 Battery를 충전 하는 시스템

2) 충전 시스템은 AC 충전과 DC 충전이 있으며, AC 충전은 EVSE를 통해 충전함

3) 충전 예:

EVSE

2010 Ray EV OBC(3.3kW)

4) 기술방향

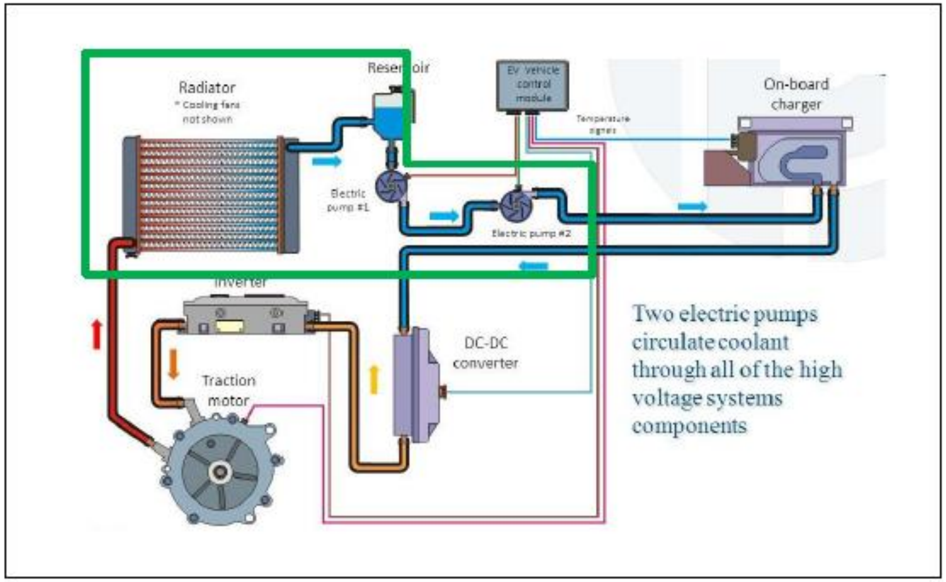
- 충전기 용량증대: 3.3kW→ 6.6kW→11kW→22kW
- 출력 밀도 : 1.0kW/liter → 2.5kW/liter (고주파수 전력 변환)

냉각 장치

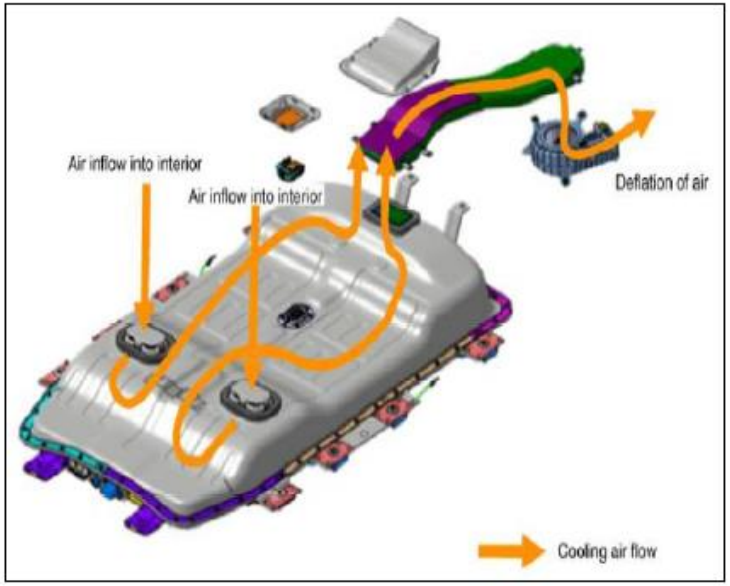
1) 전동기, 인버터, 충전기, LDC, battery 등 고전력 장치의 냉각 장치

2) 냉각 장치는 차량의 동작시, 주차시(충전시) 계속 동작되는 장치로 차량의 수명과 동등한 수명을 보증해야 하는 장치

3) 수냉식 냉각 예

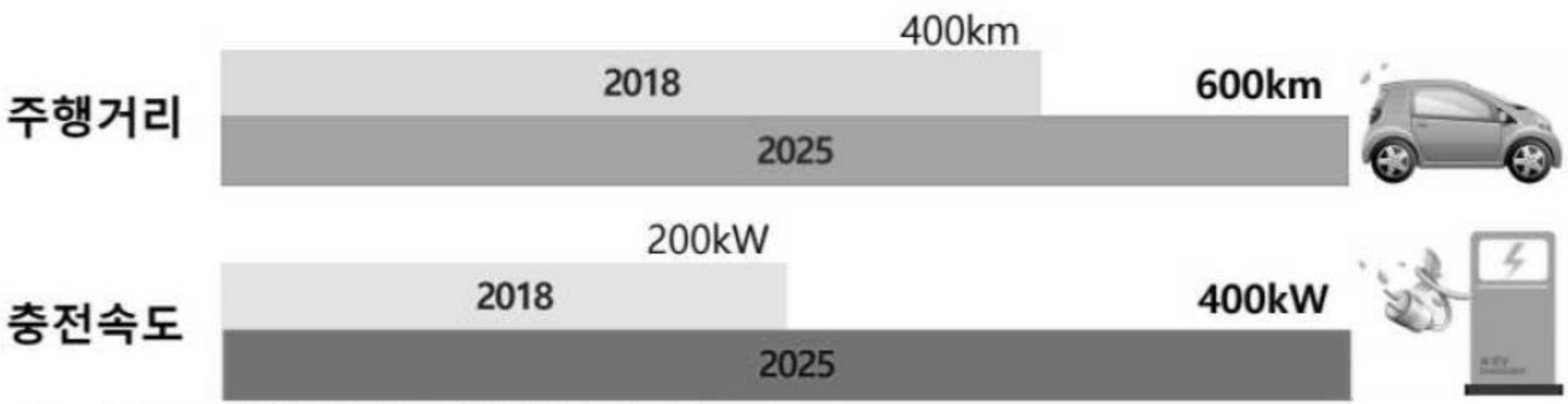


고전력 변환 장치 강제 수냉



Kia Soul Battery 냉각(강제 공냉)

2030 전기차 기술전망



Ref: 자동차 부품산업 활력제고 방안, 산업통상자원부, 2018.12

	2016	2020	2025	2030
모터출력밀도 [kW/kg]	1.8	2.3	3.0	3.5
인버터출력밀도 [kW/L]	10.8	15	30	40
배터리팩에너지밀도 [Wh/kg]	110	160	200	300
공조및열관리 [향상%]	-	3%	10%	15%

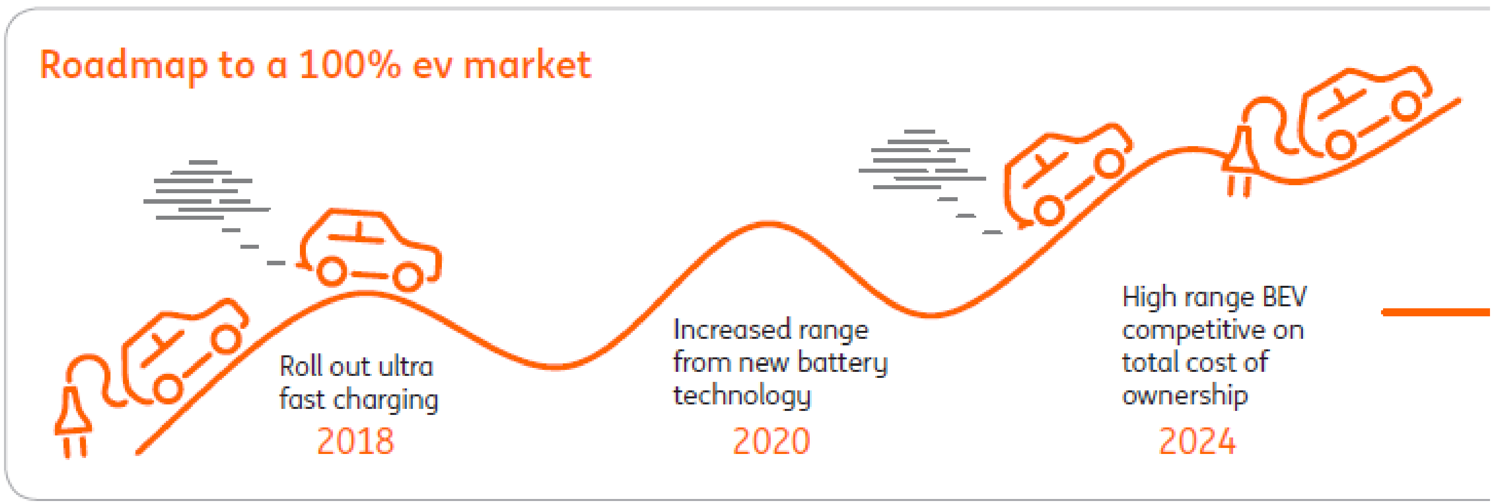
Ref: 친환경차 장기목표 수립을 위한 정책환경 연구, 2018.2

국내 보조금 정책

- 전기자동차 구매보조금 (2018년 기준)
  - 전기승용차 - 20,000대, 대당 최대 1천2백만원 지원
  - 전기버스 - 150대, 대당 최대 1억원 지원
  - 보급사업 미실시 지자체 거주자들은 한국환경공단을 통해 보조금 신청 가능
  - 보급 시행 지자체 144개('17) 에서 156개('18)로 확대
  - 신청서 접수후 2개월 이내 차량 미출고시 선정 취소 또는 대기자 변경

- 충전기 설치비
  - 급속충전기 - 1,070기, 기당 50백만원 (국가직접설치)
  - 완속충전기 - 12,000기, 기당 3백만원(자치단체 보조)
  - 완속충전기는 비공용, 부분개방공용, 완개방공용 등 공유범위에 따라 차등 지급

Electric shift challenges Car industry



100% BEV market in Europe

2035

- Europe's competitive advantage in powertrains disappears.
- More outsourcing and stronger competition in BEV powertrains.
- Commoditization of powertrains and loss of value and jobs.

- New opportunities in sustainable energy, charging infrastructure and mining.
- Value in automotive moves from hardware to services. Clean and cost efficient transports boost (private) leasing and car sharing.

Barriers limit demand for BEVs

Renewed interest in electric cars

Concern about the environmental impact of cars, emission regulations and improved battery technology have led to renewed interest in electric cars. A number of battery electric cars have been released such as the Nissan Leaf, Renault ZOE, BMW i3 and Tesla Model S. The Tesla in particular has demonstrated that rethinking the concept of a battery electric car, can lead to a more competitive vehicle. This has convinced other car manufacturers that BEVs are the way forward.

Accelerated development of electric cars

As a result, a lot of car makers are now driving the EV market. Opel launched the Ampera-e. Tesla itself plans to launch the Model 3 in 2017. Ford wants 40% of it's models to have an electric version by 2020. VW plans 10 models by the end of 2018 and 30 by latest 2025.

Still a niche

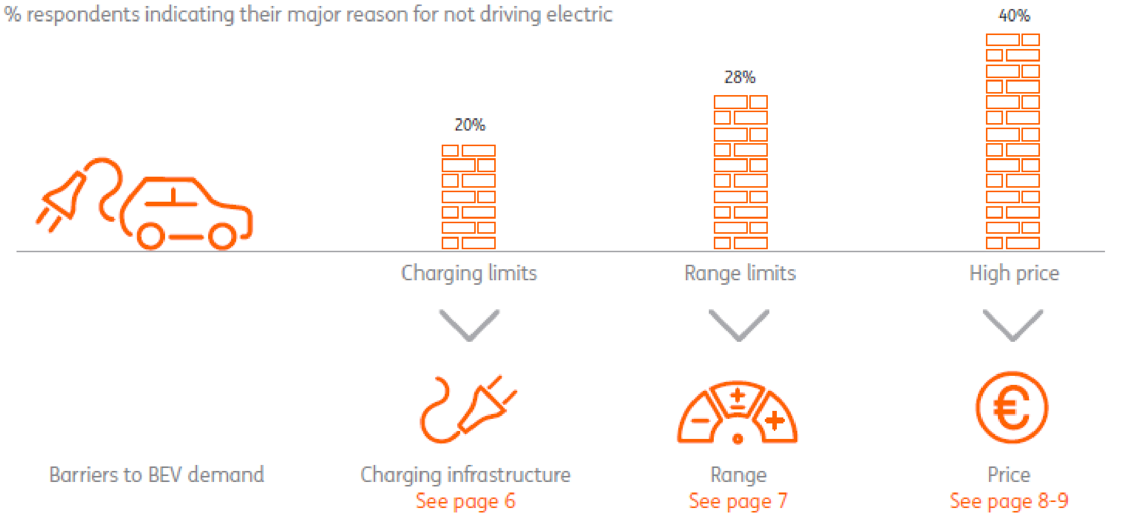
Although the focus on electric vehicles is increasing, their current share in the car market is still very limited. In Europe (EU + Norway) 1.3% of passenger cars sold in 2016 were electric (battery electric BEV and plugin hybrid PHEV). Of the total car fleet 0.2% is electric. In China, where over 40% of global EVs (BEV and PHEV) are sold, the share in sales is just under 1.5%.

Barriers to driving electric

To end the dominant position of ICEs, BEVs will have to work on the 3 major barriers for demand. According to consumers the most important reasons not to choose an electric car are:

Consumers mention 3 major barriers to BEV demand

% respondents indicating their major reason for not driving electric



Source: ING Question of the day – 47,000 respondents in the Netherlands (remaining 12% chose other reasons)

Charging Infrastructure

Explosive growth in charging infrastructure

Access to (quicker) charging infrastructure is a requirement for BEV demand. In 2010 the number of charging stations globally was minimal. In 2015 there were close to 1.5 million charging points. The growth in EV infrastructure has been explosive. In Europe, the total number of charging points (public or semi-public) has risen to 112,500.

Number of charging points almost equal number of gas stations in Europe

121,000
gas stations* (2016)

112,500
charging points* (2017)

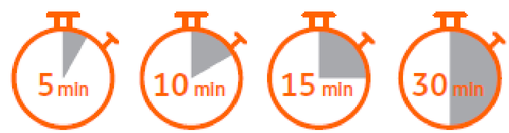
Sources: *Fuelseurope (1 station can have multiple tank points), EAFO

Competition fueling further growth

To stimulate growth in electric vehicles, national and local governments subsidize charging infrastructure. At the same time market parties are seeing charging infrastructure as an interesting growth market. Demand for charging points has risen sharply in countries such as the Netherlands and Norway. Major markets like France and Germany are catching up. The charging infrastructure market should become even more interesting as BEV numbers and battery sizes (more kWh) grow. In the Dutch market, companies have been fighting over highway locations. Furthermore there is an increasing number of parties, such as retailers (supermarkets), offering free charging to (attract) customers.

Maximum acceptable time for charging en route of people considering BEV

% of respondents



14% 23% 37% 25%

Source: ING Question of the day, 44,000 Dutch respondents, 2/3 considering BEV

Charging speed is essential

Although the number of charging points has grown, the majority of these points are 'normal' or 'slow' charging. The speed of charging is however just as important. Especially for those without the ability to charge at home or people driving long distances.

Ultra fast charging

Consumer research shows the speed of charging will need to improve. A number of companies, including infrastructure providers and car manufacturers, are involved in an ultrafast charging corridor project. This should enable BEVs to charge 300 kilometres in 20 minutes from 2018 onwards. Technological advancements, mainly cooling related issues, will have to further decrease charging times in the future. The Porsche Mission E, set for launch in 2020, is targeting a 400km range in less than 15 minutes.

Range Anxiety

Majority of consumers want over 400km range from BEV

Most BEVs on today's market have a range of 200 to 300 kilometres, depending on driving style and weather conditions. Rationally, looking at average daily driving distances, this should be enough. Research by ING however shows most consumers expect more. New BEVs will have to jump this barrier.

Minimum distance I want to be able to drive on 1 charge to consider a BEV

Cumulative % in orange

Cumulative %	%	Distance
100%	24% do not wish to consider BEV at this time	
76%	15%	800 km
61%	26%	600 km
35%	28%	400 km
7%	6%	200 km
1%	1%	100 km

Source: ING Question of the day with over 52,000 Dutch respondents.

2020 onwards: next generation featuring new battery technology

To get towards ultra high ranges and completely eliminate range anxiety, further developments in BEV technology are needed. More efficiently designed cars, more scale in production, more efficient electric motors and, above all, more efficient batteries.

2016-2020: new generation - towards acceptable mileage

Tesla has shown that its models can touch ranges up to 600km, be it at a high price. New models and lower battery prices should bring ranges of 350-500 km to more affordable cars in the next few years.

Pre 2016: first generation with limited appeal

1st generation BEVs with 100km-200km ranges have remained niche vehicles. This despite limited daily needs in terms of driving. An average German car owner drives 36.5km per day[1] and the increasingly aging population could bring this down further. Range anxiety, however, prevents people from settling for a low range.

Improving energy density

Improvements in battery cell density, meaning more energy per cell (more energy in Wh per kg), helps increase range and decrease battery pack weight and cost. In 2011 the Nissan Leaf reached 90 Wh/kg per pack[2]. In 2017, the Opel Ampera-e is close to 140 Wh/kg. Tesla leads with an estimated 170 Wh/kg and is introducing an improved cell type. Meanwhile battery manufacturers are working on other chemistries, such as solid state batteries, to increase energy density by a factor of 2 to 3. Toyota plans to market solid state batteries as early as 2020. News reports have indicated Bosch, VW and Samsung also look set to further develop these batteries for BEV use.

Sources:

1 Kraftfahrt-Bundesamt

2 Bloomberg New Energy Finance

Battery Costs

Battery pack costs decrease rapidly

Battery prices for BEVs have decreased quickly. Costs went from an average $1000/kWh in 2010 to around $300 in 2016. Current cost leaders are already moving towards $150 per kWh.

Price gap still remains

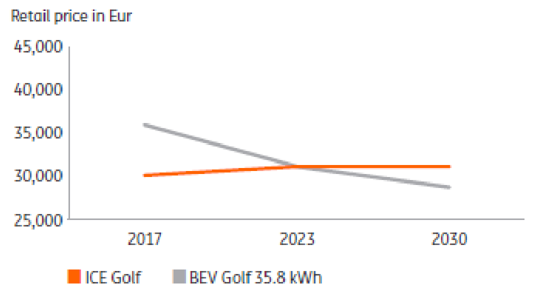
The price gap between BEV and ICE however still exists. For example the VW Golf, the best selling car in Europe and available as ICE and BEV, shows that the BEV version retail price in Germany is almost 20% higher than a comparable petrol version. Continued improvement in battery chemistry and production methods should however bring down battery pack prices towards $100/kWh in 2025[1]. This could theoretically see the retail price of the current e-Golf equate to that of a (petrol) ICE Golf in 2023. But consumers will also demand a higher range than the 200-300km currently available on a 36 kWh battery. If theoretically equipped with a 60 kWh battery, range could be pushed towards 500km, but the break-even point moves to 2028.

Source:

1 Bloomberg New Energy Finance

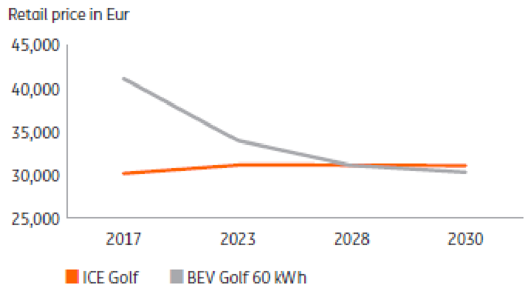
BEV VW Golf breaks even with ICE price in 2023

German retail prices (excl. government incentives) 2017 VW Golf ICE vs e-Golf 35.8 kWh*



Equipped with a longer range battery, break-even point moves to 2028

E-Golf if equipped with a 60 kWh battery vs ICE GolF



* e-Golf compared with TSI 125hp DSG 5dr. Comfortline. ICE price corrected. for extra equipment e-Golf (nav pro, LED light, media control / usb, climatronic, driving profiles). ICE added 1,000 euro for expected emission regulations costs from 2021. Forecasted battery pack cost based on Bloomberg New Energy Finance. Calculated with 10% margin and 19% VAT into German retail price.

BEV - higher costs and lower margins

The electric powertrain itself (electric motor including a simple 1 ratio gearbox) of a BEV is currently estimated to cost €1,500** on average. This is about half the average cost of an ICE powertrain (combustion engine, gearbox, exhaust etc) of €3,000. However, once the battery pack is added (close to €8,000 for a 36 kWh pack at 2017 average battery price) costs rise above those of an ICE. To make retail prices more palatable, manufacturers generally accept lower margins on BEVs.

BEV costs have downward potential, while ICE costs are expected to rise

BEVs however have potential to decrease in cost. Simpler design, easier manufacturing and increased volume should decrease production costs. Bloomberg New Energy Finance forecasts battery prices at just over $70 / kWh in 2030. At the same time ICEs will face higher costs due to stricter emission regulations. This could add an average €1,000 to the cost of an ICE after 2020.

** Sources: Technische Universität München, McKinsey, Roland Berger

Cost Competitive on 2024

Total cost of ownership BEV strongpoint

When purchasing a car it is important to look beyond the purchase price. Running costs can make a big difference to the total cost of ownership (tco). BEVs benefit from a lower tco than ICEs thanks to:

- Electricity costs being lower than fuel costs, hence a BEV will save money based on cost per km.
- With a less complex powertrain, a BEV will generally require less repair and maintenance than an ICE.

Other tco components will vary per car and per market. Road tax is an example of this. Depreciation, which is the main tco component, is difficult to determine, although long range cars (in particular the Tesla) have shown favourable residual values. High range BEVs should be attractive to consumers buying second hand, as it reduces their operational costs.

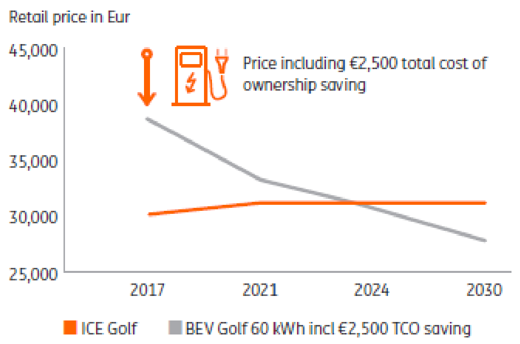
Energy savings

As stated on page 8, a long range BEV thus needs more time to reach break even when comparing retail prices. However, we estimate a 60 kWh e-Golf will save money on its total cost of ownership. A German customer, capable of charging at home, can save €500 per year on energy costs alone. If we assume average car ownership of 5 years (at 15,000 km / year), this results in a €2,500 saving.

Total cost of ownership helps long range BEV

As stated on the left it is difficult to forecast all costs of ownership. A high range BEV is however expected to be competitive on all cost factors, while saving on energy costs. If we take into account the €2,500 tco saving and subtract this from the calculated retail price, the high range BEV is able to achieve tco parity with a comparable petrol car in 2024. The year of tco parity will vary by market. Electricity prices are relatively high in Germany. Other European markets could hit tco parity earlier.

Total cost of ownership parity for 60 kWh BEV in 2024



Taking into account the total cost of ownership advantage (as described left) the price is reduced by €2,500. These total cost of ownership savings were calculated using the advantage of charging at home vs. refuelling a petrol car. Calculation is based on 5 year ownership in Germany of a BEV driving 15,000 km / year.

EV changes the Value Chain

A market dominated by battery electric cars has huge consequences for all parties in the value chain. This requires Europe's Automotive industry and its employees to prepare for change.

Different parts, different value chain

The powertrain of a car involves components generating power and delivering this to the wheels. A BEV powertrain differs considerably from an ICE powertrain. Exhausts, transmissions and engine components are exchanged for electric motors, battery packs and power electronics (to control electric power). It is estimated a BEV powertrain has around 200 components while an ICE carries 1,400 components[1]. Almost a third of the value of the Automotive supply chain is powertrain related and threatened by the shift to electric powertrains.

Combustion engines in Europe

Europe has been at the forefront of internal combustion engines for passenger cars since the end of the 19th century. In 2016 there were over 90 locations for engine and transmission production in Europe (incl. Russia and Turkey). Europe produces around 22 to 23 million engines and gearboxes per year[2]. This is close to 25% of the total global light vehicle engine and gearbox production and represents a value of 65 to 70 billion euro.

Sources:
[1] Friedricht Ebert Stiftung (The future of the German Automotive Industry)
[2] based on IHS data

Change from ICE to BEV results in global USD 217 billion[3] powertrain segment swapped for BEV components

ICE powertrain
Total $217 billion

1,400 components

Engine
$100 billion

Exhaust
$39 billion

Transmission / drivetrain
$71 billion

→

BEV powertrain

200 components

Electric motor
(+ power electronics)

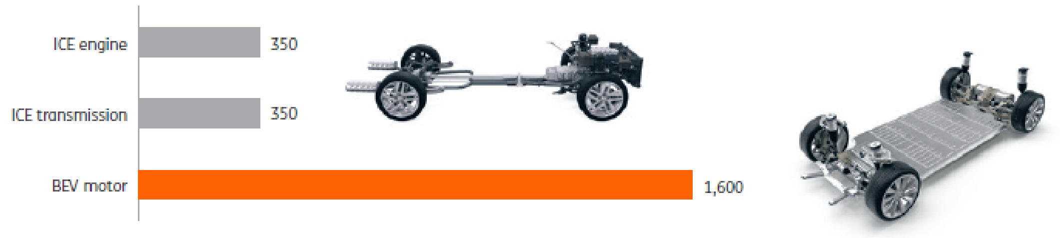
Battery pack

[3] Roland Berger 2015 turnover, note that $7 billion out of $217 billion is hybrid and BEV related

More raw materials, Less labor

Less labour required for BEV powertrain production

Estimated average components per employee per year



Data from various ICE and BEV car manufacturing plants shows that the number of electric engines/ motors produced per employee is significantly higher than for internal combustion engines. We expect this to rise further as BEV volumes increase. Although there is still little data on battery pack production, this process is also highly automated.

Source: ICE Estimates based on production plant info from BMW, VW, Daimler and Nissan

BEV needs raw materials

While a BEV does not carry a significant number of (moving) parts, it does require additional raw materials, mainly for its batteries. Besides lithium, materials used include nickel, cobalt, graphite, manganese and aluminium.

Raw materials not seen as future constraint

Although exact amounts per manufacturer are unknown it is estimated[1] that a 70 kWh Tesla battery pack holds 63kg of lithium and 54kg of graphite. This is still only part of the story as the total battery pack weight is around 450kg. Demand for raw materials will rise in a BEV dominated market. Supply is generally not considered as a future constraint.

Geopolitical risks can influence prices

Price swings in case of over- or undersupply are however possible. Geopolitical risks exist as mining of some materials is sometimes concentrated in certain countries. For example, around half of global cobalt production is in the Democratic Republic of the Congo. Location of raw materials can also benefit the manufacture of BEVs in some countries over others. China for example has lithium reserves and mining, while the US and Europe have only just begun to look at building a lithium mining industry.

Less dependent on labour

BEV manufacture might require a lot of raw materials, but a BEV requires less labour in production. Electric motors are smaller and less complex than internal combustion engines. Highly automated production is possible for battery packs and electric motors.

Powertrain shifts to Suppliers

Manufacturers more reliant on suppliers

Traditionally ICE manufacturers develop and assemble engines and transmissions themselves based on a vertical integration model. The situation is different in BEV powertrains. A lack of knowledge and production capacity means car manufacturers are relying on suppliers to help them build BEVs. Although many European manufacturers are now also developing BEV components themselves, the transfer from ICE to BEV can threaten their position in powertrains.

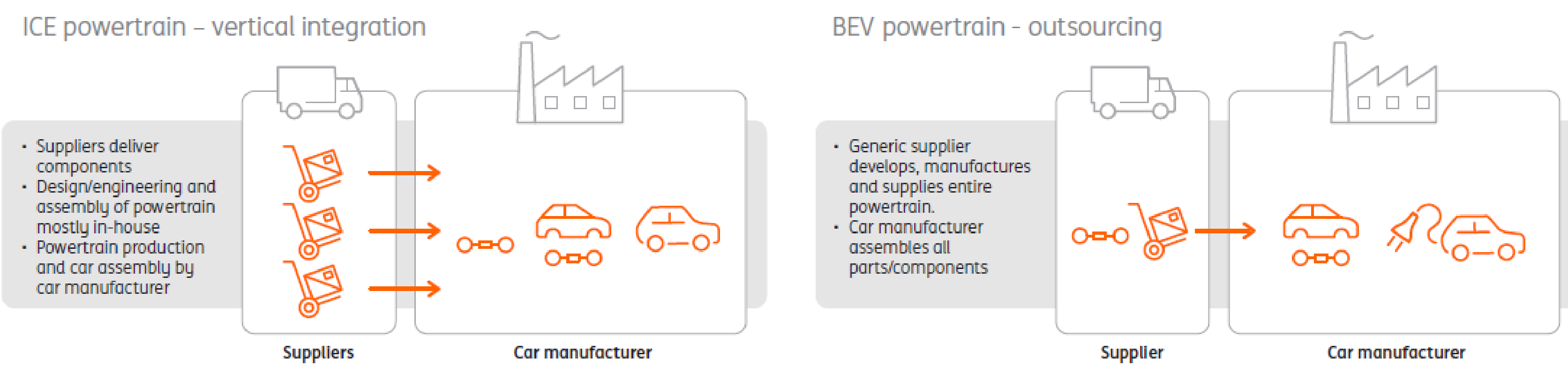
One stop shopping for BEV powertrain

Major battery suppliers and 'traditional' generic suppliers such as Bosch and Continental have moved into electric powertrain development. Unlike with ICEs, where they supply parts, this gives them the opportunity to become a one-stop shop by supplying entire BEV powertrains. The electric motor, featuring less components and more automated production, replaces the more complex ICE engine and (separate) transmission.

Integration vs. outsourcing

The recent case of the new Chevrolet Bolt/Opel Ampera-e is a good example of how BEV production could lead to more outsourcing. General Motors outsourced the entire powertrain to its supplier, LG Chem. Most BEV models have battery packs from major suppliers such as LG, Samsung and Panasonic. In electric motors we currently see a lot of outsourcing, although some manufacturers aim to develop their own motors in the near future.

BEV powertrain more likely to be outsourced

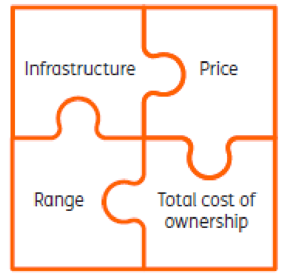


Value shifts from Product to Service

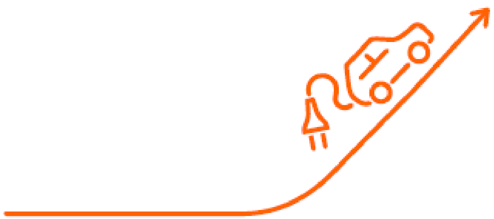
Barriers to BEVs broken one by one

Barriers broken
- Charging infra 2018
- Range 2020 onwards
- Price / Cost of ownership 2024

Puzzle fits in 2024



Growth path will bring BEVs near 100% market share in 2035



Change in components as BEVs replace ICEs

From internal combustion engine, transmission and exhaust....
...to electric motor, battery pack and power electronics

Powertrain from differentiator to commodity

+ automation	+ outsourcing
+ raw materials	+ competition
– labour	– differentiation

Europe's advantage disappears, decreases powertrain value and reduces jobs.

Value shifts to services

BEVs help consumers with more affordable transport as costs of operation decrease. Mobility as a service solutions, such as leasing and sharing, can facilitate this.

Thank You !

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