Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

Market Preparation of Hydrogen Mobility

The situation in Germany

ALDE Seminar, Brussels | 15.03.2011

NOW GmbH | Klaus Bonhoff | Managing Director/Chair

A global industry group assessed the potential of alternative power-trains for passenger cars in Europe based on proprietary company data

Core questions

How do FCEVs, BEVs, and PHEVs compare to ICEs on

- Cost
- Emissions
- Energy efficiency
- Driving performance?

What are viable production and supply pathways?

What are the potential market segments for the different power-train technologies?

A portfolio of power-trains for Europe:
a fact-based analysis

Press release 8th November 2010, Brussels[1]

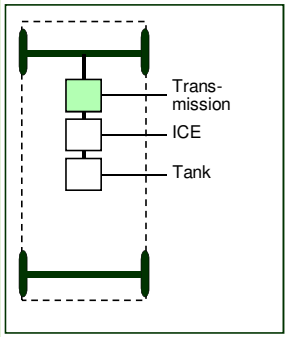
1 Report can be downloaded from
www.now-gmbh.de/presse/studie-entkarbonisierung-individualverkehrs.html
www.europeanclimate.org/index.php?option=com_content&task=view&id=92&Itemid=42

A portfolio of power-trains for Europe: A fact based analysis – The Portfolio

ICE power-train | Transmission | Electric power-train | Battery | FC power-train

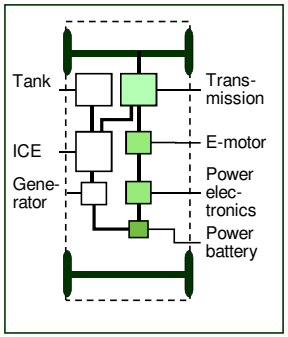
Internal combustion engine (ICE) vehicle

Current technology (2010)



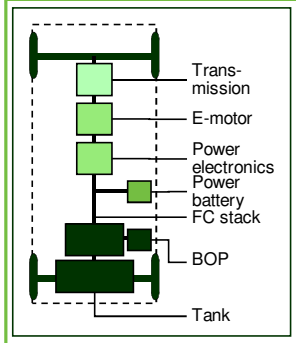
- **Conventional** internal combustion engine
- **No dependency** on electric infrastructure
- **High fuel consumption** and exhaust emissions
- **High range**: typically 800-1200 km

Advanced (2015/20)



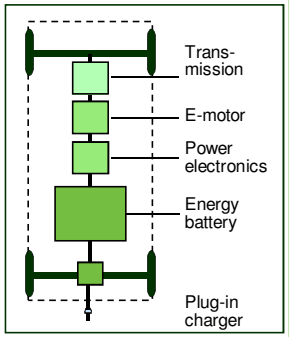
- **Parallel** hybrid configuration of electric and ICE drive; also known as hybrid electric vehicle (HEV)
- **ICE is primary mover** of the vehicle with support from small electric motor
- **Small battery** charged by the ICE
- Fully electric driving only at **low speed** for **smaller distances** (<5 km)
- **Better fuel economy** than conventional ICE

Fuel cell electric vehicle (FCEV)



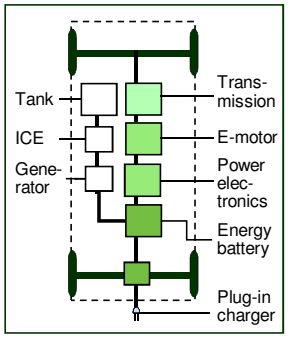
- **Series** configuration of fuel cell system and electric drive
- **Fuel cell stack** based on PEM technology
- Hydrogen tank pressure typically 350 or 700 bar
- **Medium range**: typically 400-600 km

Battery electric vehicle (BEV)



- **Purely electric** drive
- Large battery capacity, Li-ion technology
- Only charging of battery **from the grid** while stationary[1]
- **Short range**: typically 150-250 km (based on battery weight of 70-180 kg[2])

Plug-in hybrid electric vehicle (PHEV)

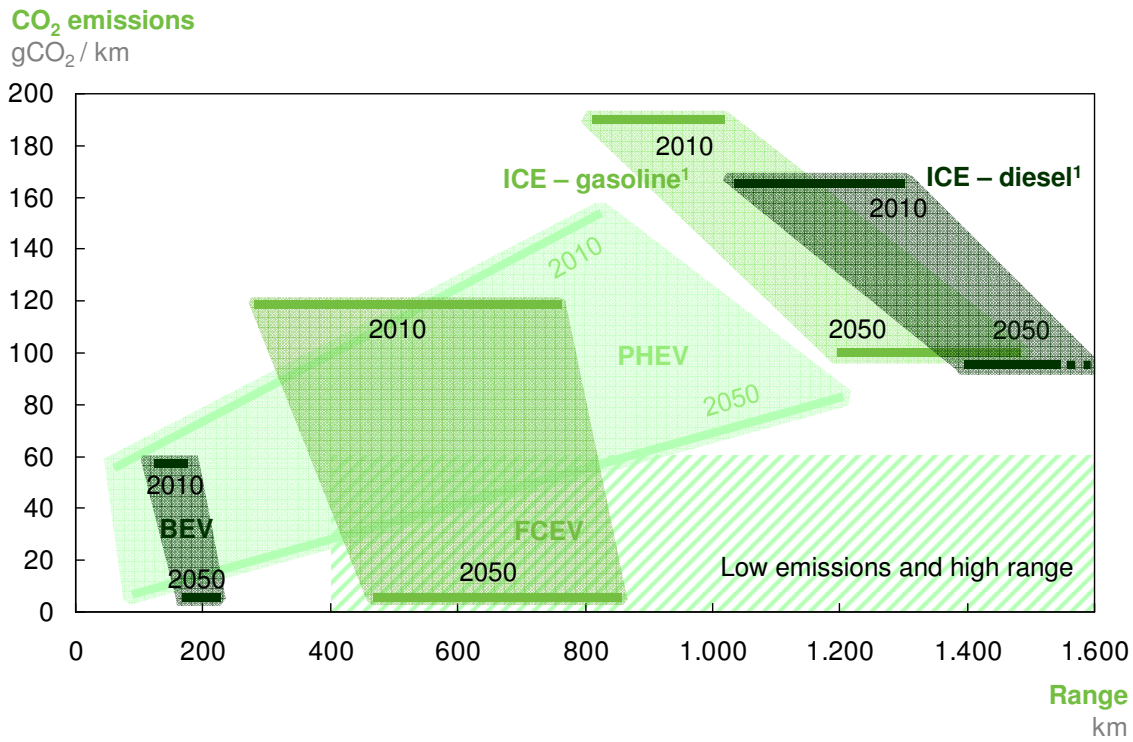


- **Series hybrid** configuration of electric and ICE drive[3]
- **Smaller battery capacity** than BEV, (Li-ion)
- Vehicle can be **plugged-in** to charge from the grid
- **Small ICE**-based generator for larger range ('range extender')
- **Short range**: typically 40-60 km) electric driving. (based on battery weight of 20-80 kg[2])

1 Exchange of battery pack is possible, but not considered in this study
2 2020 values averaged over A/B, C/D and J segments – a ~50% decrease over 2010. Although considerable cost improvements in battery technology are considered in the study, it is not expected to achieve significantly lower specific volumes or weights beyond 2020
3 Other configurations are possible
SOURCE: Study analysis

A portfolio of power-trains for Europe: A fact based analysis – The Potential

C/D SEGMENT



➔BEVs and FCEVs can achieve significantly lower CO_2 emissions, while BEVs show limitations in range.

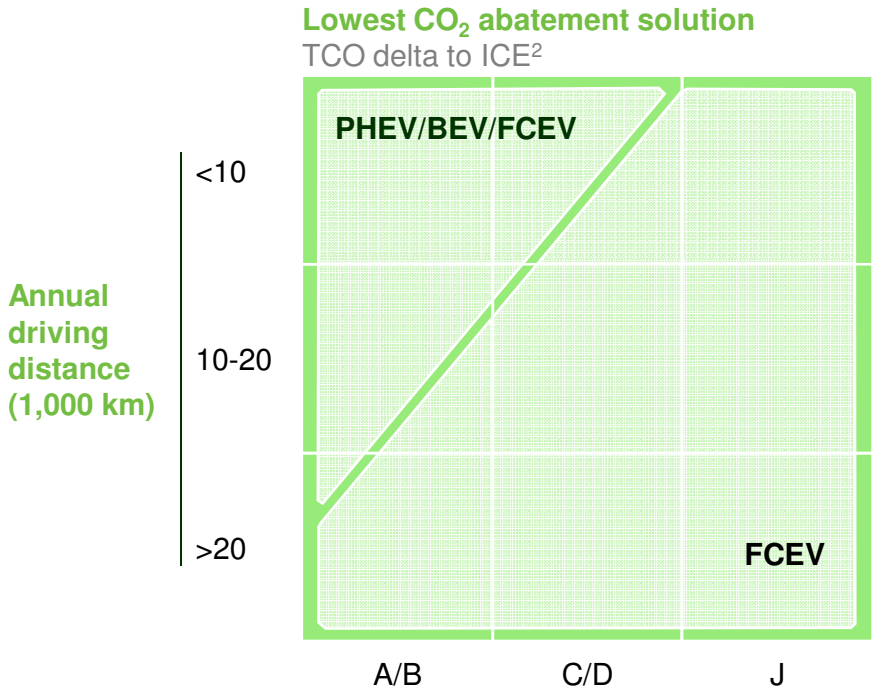
1 ICE range for 2050 based on fuel economy improvement and assuming tank size stays constant. Assuming 6% CO2 reduction due to biofuels by 2020; 24% by 2050

SOURCE: Study analysis

A portfolio of power-trains for Europe: A fact based analysis – The FCEV Advantage

EUR/year/car[1], assuming no cost of CO2

2050



➔ Long term, FCEVs are the best solution for CO_2 abatement in large vehicles with high annual mileage.

1 Constant lifetime, but different total driving distances (90,000 km; 180,000 km; 360,000 km)
2 Calculated as ICE TCO minus lowest FCEV/BEV/PHEV TCO. Negative numbers indicate a TCO advantage over the ICE

SOURCE: Study analysis

The results of the factual study are promising for fuel cell technology

CO_2 – reduction…	BEV and FCEV are the main powertrain technologies capable of achieving the most ambitious **95% CO_2 emission reduction** as targeted by the EU (EU 2050 Roadmap)[1]
Robustness…	Electric vehicles can be fueled with a broader range of feedstocks than ICEs
Technology…	More than **15 million km** on the road demonstrate that **technological hurdles** and **safety issues** have been overcome, FCEV are being geared up for **industrialization**
Cost Competitiveness…	The **initial TCO disadvantage** towards ICE is primarily based on the lack of economies of scale and will **converge** with the industrialization of FCEV. **Fuel cell system cost** are expected to decrease by **90%** until 2020[2]
Market potential…	FCEVs play a **complementary** role to BEVs and PHEVs. FCEVs are ideally suited to medium/larger cars and longer trips accounting for 50% of all cars and 75% of CO_2 emissions. FCEVs are therefore an **effective low-carbon solution** for a large proportion of the fleet
Infrastructure…	**Due to HRS** technology improvement and ramp up, capex per station has the potential to decrease by ~50% until 2020, however significant **investment** is needed for a large-scale roll-out
Incentives and financing instruments…	Given a reasonable **incentive system** and **funding instruments**, the TCO disadvantages many already be leveled out by ~2020
Next steps…	**H_2 Mobility** business case **Germany** as a pilot and lead market

1 Fuel and power production on the basis of renewable energies and/or CCS technology
2 Assuming an uptake of one million FCEV in 2020 (cumulative carpark)

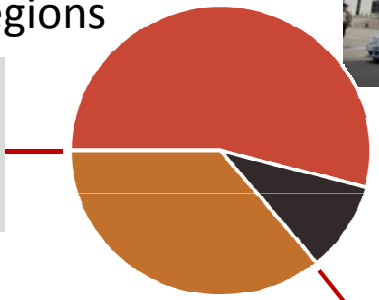
Preparing Hydrogen and Fuel Cell Markets: National Innovation Program (NIP)

Transportation 54% *

- Includes H_2 production and infrastructure
- Expanding vehicle fleets and hydrogen infrastructure starting from key regions

95 projects
Funding: € 229 million
(BMVBS, Jan.2011)


Source CEP



Stationary Applications 36% *

- FC micro CHP for residential use
- Industrial FC gensets for CHP and trigeneration


Source Vaillant


Source Telekom / PASM

Special Markets 10% *

- IT, telecommunications
- Logistics, leisure and tourism markets


Source BMV

* Planned distribution according to National Development Plan v 2.1.

Clean Energy Partnership
Planning Through 2013

Ein Projekt im Nationalen Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie

Region	Start date	Current no. of public HRS	Total no. of public HRS planned[2]	No. of FCEV planned[2]
Berlin	2002	2	4[6]	63
Hamburg	2008	1[5]	4[6]	25
Nordrhein-Westfalen	2010[3]	0	1	10
Baden-Württemberg	2010[3]	1	4	20
Hessen	2011[4]	1	2	15

1 Additional industry projects e.g. Chemergy not included

2 Planning horizon shown is only until 2013

3 Part of CEP since 2010, rollout of actual demo project tbd

4 Request for participation was submitted in 2010, decision about admittance in 2011

5 Only partly accessible by public

6 HRS at A 24 (highway from Berlin to Hamburg) not included as planning unclear

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Hydrogen Production
Focussing on Wind Power and Biomass

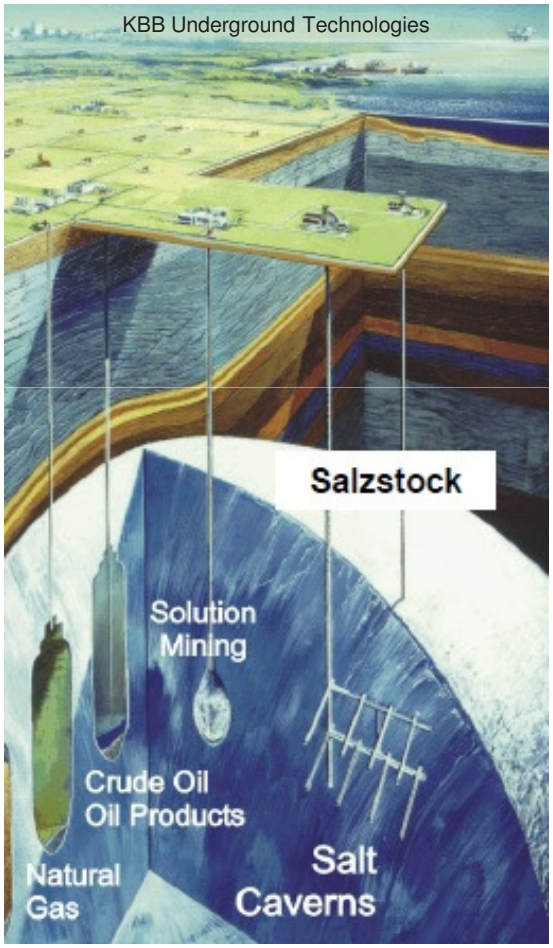
Increased Wind Capacity will make wind power the most important source for hydrogen production beyond 2020

Large scale Electrolyser is a key technology

Studies show potential for wind-hydrogen-systems to store large quantities of fluctuating energy

Biomass will play an important role as feedstock for hydrogen production beyond 2020

Gasification technologies are key



"H_2 Mobility" Initiative – Overcoming the Chicken and Egg Dilemma

- Memorandum of Understanding for "H_2-Mobility" signed Sept. 10th 2009 in Berlin
- Ten key stakeholders from industries (OEM, oil, utility & industrial gas) and NOW as public-private-partnership
- Intention to build up hydrogen fueling infrastructure and establishing Germany as lead market

DAIMLER EnBW THE LINDE GROUP AIR LIQUIDE NOW OMV AIR PRODUCTS SHELL TOTAL eni VATTENFALL

H_2 Mobility

H_2 Mobility defined two successive phases

Phase 1: 2009 – 2011

- Techno-economic evaluation of the feasibility to deploy a network of HRS alongside the expected deployment of FCEVs in Germany by 2015 (2009 – 2010)
- Definition of the future Consortium Agreement Contract / Partners negotiation phase (2011)
- Deployment of new HRS supported by the German Administration (Konjunkturpaket II subsidy scheme)

Phase 2: 2011+

- Implementation of the hydrogen retail infrastructure by parties participating in the consortium

In Phase 1, 17 private companies and NOW developed roll-out scenarios for a hydrogen infrastructure and FCEVs

Participating companies

Car OEMs	DAIMLER, BMW, HYUNDAI, KIA MOTORS, GM, INTELLIGENT ENERGY, NISSAN, TOYOTA, VOLKSWAGEN
Industrial gas companies	AIR LIQUIDE, AIR PRODUCTS, THE LINDE GROUP
Oil and gas companies	TOTAL, OMV, Shell, eni
Utilities	EnBW, VATTENFALL
Govern-mental Org	NOW – Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

Main achievements

- Bottom-up development of **consistent** infra-structure and FCEV **roll-out scenarios**
- Assessment of econom-ics associated with hydrogen infrastructure rollout in GER
- Analysis of **sensitivities** and quantification of **risks and opportunities**

Industry group evaluated roll-out scenarios for Germany applying a "clean room" approach and an effective project organization

Project approach and working groups with industry

Industry group: Production and supply
- H_2 production roadmap
- H_2 cost
- CO_2 footprint

Industry group: Hydrogen refueling stations
- HRS types
- Capex/Opex
- Specifications

Industry group: Customer value proposition
- FCEV roll-out
- Rollout regions
- H_2 demand

Clean Team[1]

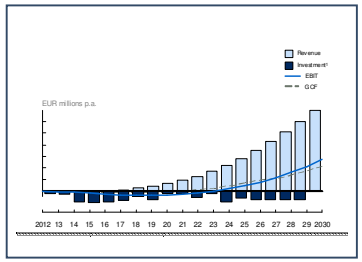
Verified and sanitized input data

Econo-mic model and network planning

Case B

Case A
- Station roll-out
- FCEV roll-out
- Regional coverage
- H_2 production and supply roadmap
- CO_2 abatement

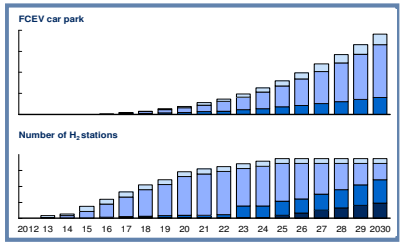
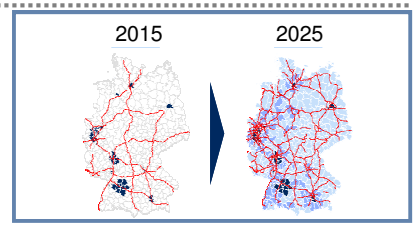
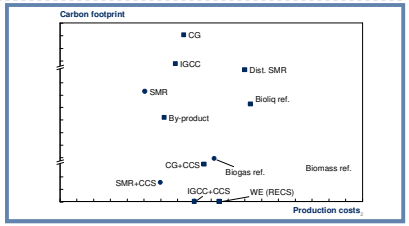
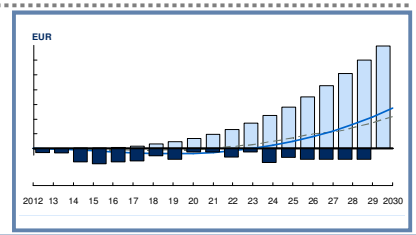
Financial results



1 Separate third-party team handling confidential data

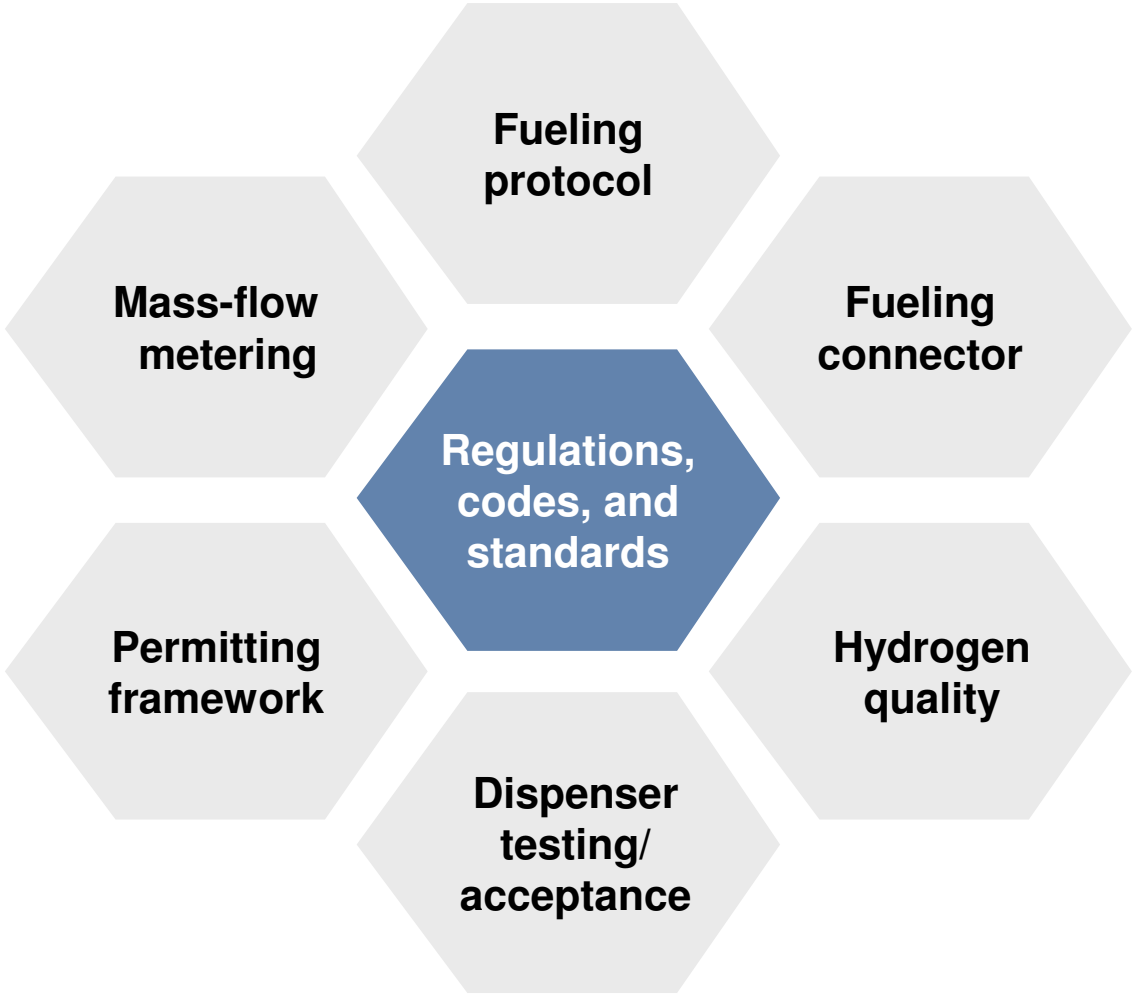
H2 Mobility

Main achievements and selected end products for pilot market Germany

Roll-out scenarios for H_2 station network and FCEVs	• Development of **FCEV roll-out** scenarios with car OEMs via "clean team" based on assumptions (e.g., incentives, market environment) • Assessment of **H_2 station rollout** and network requirements (e.g., density, sizes)	
Roll out regions and timing	• Analyses of German **regions** on traffic density, income per capita, car registrations, etc. • Definition of **"focus regions"** and connecting highways	
H_2 production and supply road map	• Assessment of **H_2 production technologies** on cost and CO_2 emissions (water electrolysis, steam methane reforming, etc.) • Definition of H_2 **production and supply mixes** focusing on CO_2 abatement, sustainability, and economic efficiency	
Holistic roll-out cases	• Description of consistent **rollout case** for Germany • **Financial assessment** of roll-out cases including NPV, investment, payback time • Evaluation of **risks** and **sensitivities**	

H_2 Mobility

H_2 Mobility alignment on regulations, codes, and standards to ensure compatibility of any HRS and FCEV



Next steps for H_2 Mobility

Roll-out scenario evaluation	Implementation plan	Stakeholder alignment and negotiations
Participants internal reviews of roll-out scenarios	Analyze incentive scheme among industry, GER government, and EC	Align with government on potential incentives
Collect feedback and update roll-out scenarios	Define business and implementation plan	Align with key stakeholders
		Negotiate future organization

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Thank you!

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