Electric Vehicles:
A Lifecycle Approach

Kasper Zom MSc
ARN Advisory
Sofia, Bulgaria
3 June 2010

Why is ARN interested in electric transport?

Goal: prepare recycling chain for e-vehicles and batteries

What ARN does to reach this goal:

- Increasing general knowledge on electric vehicles
- Acquire detailed knowledge on batteries
- Research on dismantling, safety and recycling
- Battery dismantling tests carried out by ARN & KEMA

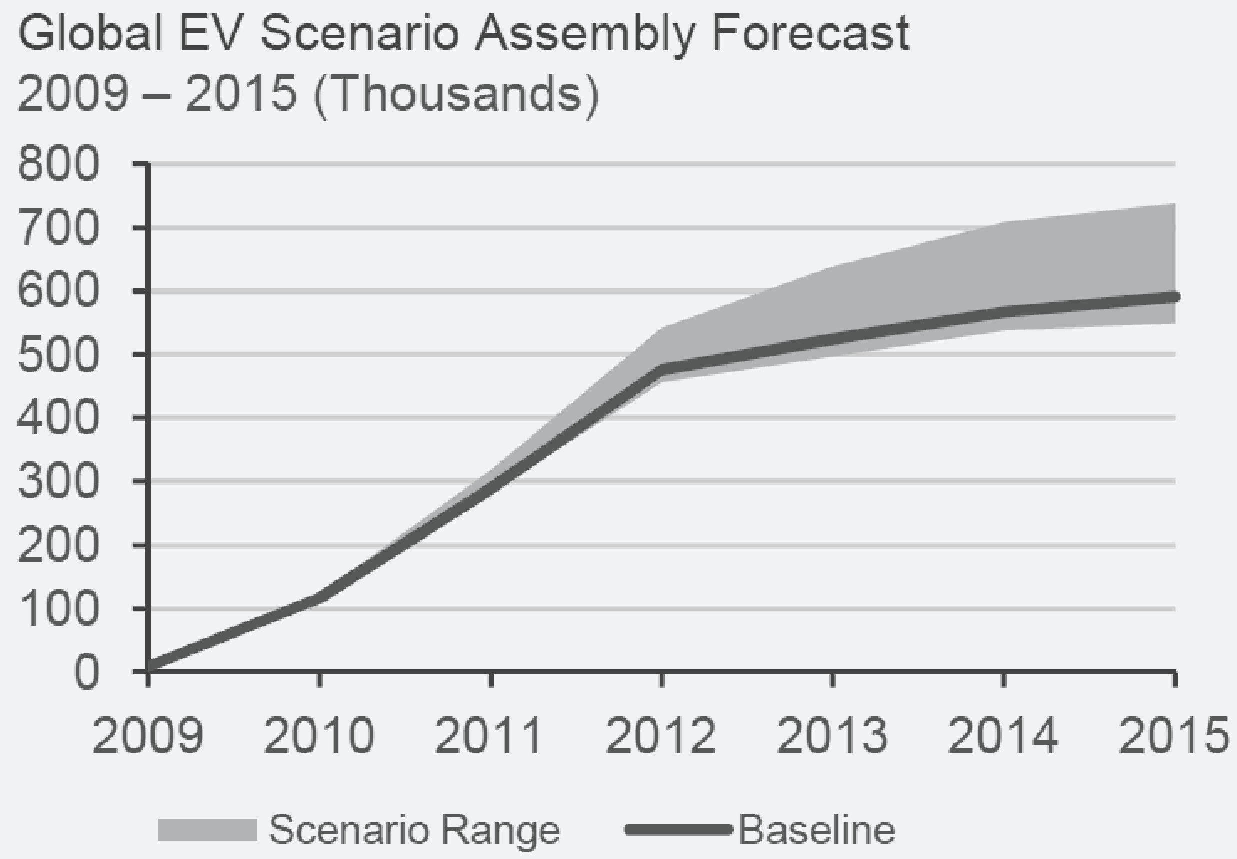
→ This presentation will show recent developments and what they mean to ARN; displayed by !

ARN

Why Go Electric?

- Energy resilience
- Limiting tailpipe pollutants and CO_2
- High energy efficiency solution

Global developments – what the experts say



Source: PwC AUTOFACTS 2009 Q4 Data Release

ARN

Ambition of the Netherlands

International proving ground for electric transport with the aim of facilitating major market introduction

Dutch Ministers see electric transport as solution for:

- Making transport truly sustainable
- Creating a strong energy position
- Providing a structural impulse to the economy
- (Positive publicity for future elections)

ARN

Key enablers for large scale introduction in NL

1. Range
2. Availability of resources (lithium, REE) !
3. Electric infrastructure & smart grids
4. Standardized plug design
5. Total cost of ownership !
6. Residual value of car and battery !
7. Safety (in case of crashes, fires, etc) !

ARN

Developments of (H)EV in NL

	Market phase	Estimated no. of vehicles
2009-2011	‘Proving grounds’	
2012-2015	Scale up	15,000-20,000
2015-2020	Continued roll-out	200,000
> 2020	Mature market	1,000,000 in 2025 ???

Measures taken by Dutch government:

- Subsidies
- Stimulating purchase by consumers (taxation)
- Stimulating R&D
- Development of electric infrastructure

ARN

Issues to talk about

- Are electric vehicles zero emission vehicles?
- Is lithium scarce and will it run out?
- Can electric car batteries be completely recycled?
- Is Li-Ion *the* power source for electric vehicles?
- Is it possible to reuse batteries?

ARN

Lifecycle Analysis

In terms of CO_2 (production, use, end-of-life):
- ~30% less emissions for electric cars

Balance will change:
- Heavy regulation of CO_2 emissions for ICE cars
- Use of unconventional oil (oil sands in Alberta)
- Shift in CO_2-prices in carbon emission market

Environmental effects of EVs:
- More water use (in production process)
- Less noise and fine dust particles
- Less acidic pollutants (e.g. NO_x)

ARN

Green Electricity Key for Real Zero Emission

- Zero emission at tailpipe shouldn't mean that emissions are moved upstream (to energy plant)

- Sustainable sources like wind power and concentrated solar power most likely replacement for conventional energy plants

- Economies of scale expected in green power with rise of new world powers like China and India

! **Zero emission during vehicle use will likely increase focus on emissions during end-of-life**

ARN

Issues to talk about

- Are electric vehicles zero emission vehicles?
- Is lithium scarce and will it run out?
- Can electric car batteries be completely recycled?
- Is Li-Ion *the* power source for electric vehicles?
- Is it possible to reuse batteries?

ARN

Lithium scarce?

ARN

World mine production, reserves and reserve base of Lithium (x10^6)

	Mine production[1]			
	2007	2008	Reserves	Reserve base
US			38	410
Argentina	3	3.2	NA	NA
Australia	6.91	6.9	170	220
Bolivia	--	--	--	5,400
Brazil	0.18	0.18	190	910
Canada	0.707	0.71	180	360
Chile	11.1	12	3,000	3,000
China	3.01	3.5	540	1,100
Portugal	0.57	0.57	NA	NA
Zimbabwe	0.3	0.3	23	27
World total	25.8	27.4	4,100	11,000

[1] Source: U.S. Geological Survey

ARN

Lithium mining and production

- 70% of lithium reserves located in triangle Chili, Bolivia and Argentina
- Sub-surface brines most important source of lithium carbonate used for Li-ion batteries
- Chili dominates supply of lithium carbonate with 44% of world total
- Half of world reserve is located in Bolivia (Salar de Uyuni): 5,4 mio ton. Bolivia plans production facility of 30,000 tons

ARN

Lithium consumption – the case

- Amount lithium carbonate consumed for vehicle batteries forecasted to grow from 1,000 metric tons in 2008 to 15,000-29,000 metric tons in 2020

- Assuming:
  4 kg lithium/EV battery
  Car sales of 70 mio in 2020 (conservative estimate)
  (H)EV share of 5-10%
  → will lead to 14,000-28,000 ton additional Li consumption

- Concerns regarding Li availability for EV batteries unfounded

! **Lithium will have limited value when recycled**

ARN

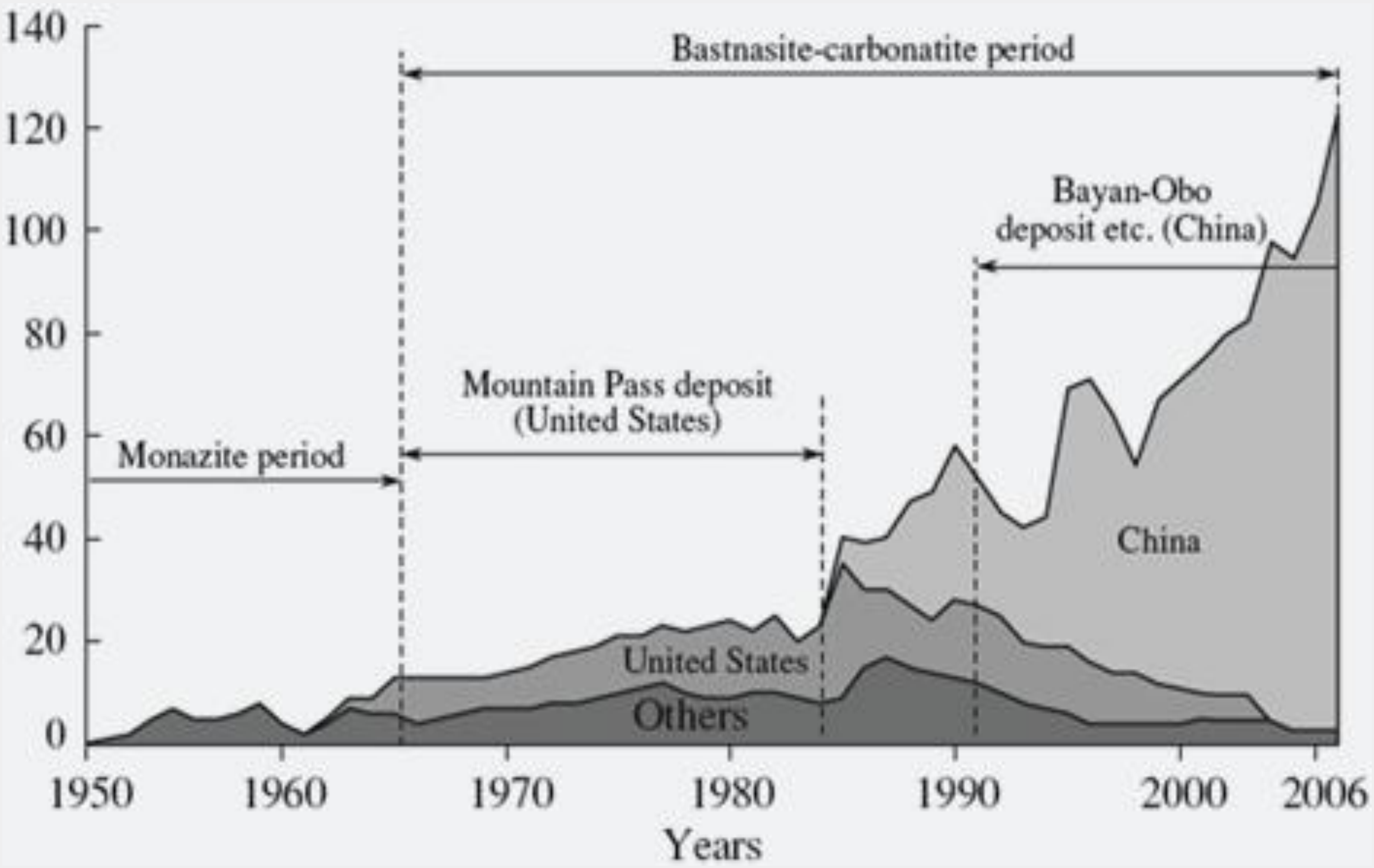
Problem: not lithium but REE

REE = Rare Earth Elements = Lanthanides group (15 elements), Yttrium, Scandium

- Used in various mobility applications:
  - Dysprosium – used in hybrid car motors
  - Lanthanum, Cerium – used in battery alloys (mainly NiMH)

- Used in ‘new technology’ :
  - solar panels
  - wind turbines
  - advanced mobile phones
  - computers and transmitting devices

Global Rare Earth production 1950-2006 (*1,000)



Source: U.S. Geological Survey

Forecast growth of Rare Earth Elements usage: 10% per annum

Element	Application	Consumption [tonnes p.a. of REO]		Growth rate [% p.a.]
		2006	2012	
Ce, La, Nd, Pr	Battery alloy	17,000	43,000	17
Dy, Nd, Pr, Sm, Tb	Magnets	20,500	42,000	13
Eu, Tb, Y	Phosphors	8,500	14,000	9
	Ceramics	5,500	9,000	9
	Others	8,000	13,000	8
Ce, Nd, La	Catalysts	21,500	32,000	7
Ce, La, Pr	Polishing powder	14,000	21,000	7
Ce, Er, Gd, La, Nd, Yb	Glass additives	13,000	14,000	1
	Total	**108,000**	**188,000**	**10%**

! **REE is crucial in range of sustainable technologies**

ARN

REE production and consumption

- 2008 global mine production REE, estimated at 124,000 metric tons.
- China produced 97%, India, Brazil and Malyasia 3%
- China limits export of certain REE metals
- Typical hybrid EV with NiMH battery contains 10-12 kg REE
- According to geologists reserves might run out in several years

! **REE is not that widely used in Li-Ion batteries; limited contribution to residual value**

ARN

Issues to talk about

- Are electric vehicles zero emission vehicles?
- Is lithium scarce and will it run out?
- Can electric car batteries be completely recycled?
- Is Li-Ion *the* power source for electric vehicles?
- Is it possible to reuse batteries?

ARN

Electric cars and recycling

	Ease of treatment	Description
Car	+	- Material combinations similar to combustion engines - Less fluids - Simplified systems
Electric engine	+	- Very little wear - Carbon brushed easily replaced - Can be remanufactured and reused
Battery	?	- Dismantling difficult - Recycling techniques are costly and yield limited returns

! **Battery recycling is main area of focus due to uncertainty in value of Li-Ion batteries**

ARN

Recycling and high-voltage batteries

- Current melting techniques require high temperature
  - Large CO_2 footprint
  - High cost

- Lithium oxide can be used in civil engineering applications

- Other techniques such as ‘leaching’ are in trial phase

- Economically viable techniques for REE recycling are needed to safeguard resource availability in Europe

ARN

Issues to talk about

- Are electric vehicles zero emission vehicles?
- Is lithium scarce and will it run out?
- Can electric car batteries be completely recycled?
- Is Li-Ion *the* power source for electric vehicles?
- Is it possible to reuse batteries?

ARN

The future of EV batteries

Li-Ion is seen as *the* battery for electric mobility

- Best energy-to-weight ratio
- No memory effect
- Slow loss of charge

Safety concerns:

- High temperature build-up during use
- Safety hazard during emergency operations
  - Lithium fires are very violent
  - Lithium reacts with water
  - Some Li-Ion batteries contain fluoride; concerns over formation of hydrogen fluoride gas during accidents

! **Safety is an important factor for ARN dismantling companies**

ARN expectations regarding batteries

- Li-Ion battery is a good in-between form and enabler for medium distance driving

- Battery cost will not come down enough for long-term profitable business model of traditional Li-Ion batteries
  - Safety issues regarding liquid electrolytes
  - Capacity of Mn and PO4-type cathode batteries still below theoretical values

Promising alternatives:
- Lead carbon: fraction of Li-Ion cost, though heavier
- Silicium oxide: sufficient resources

! **Li-Ion will be widely used for some time and recycling chain design should reflect this expectation**

ARN

Issues to talk about

- Are electric vehicles zero emission vehicles?
- Is lithium scarce and will it run out?
- Can electric car batteries be completely recycled?
- Is Li-Ion *the* power source for electric vehicles?
- Is it possible to reuse batteries?

ARN

ARN’s ideas on collection, reuse & recycling

Cooperation with manufacturers, collectors and other parties to arrange battery collection and reuse

Why?

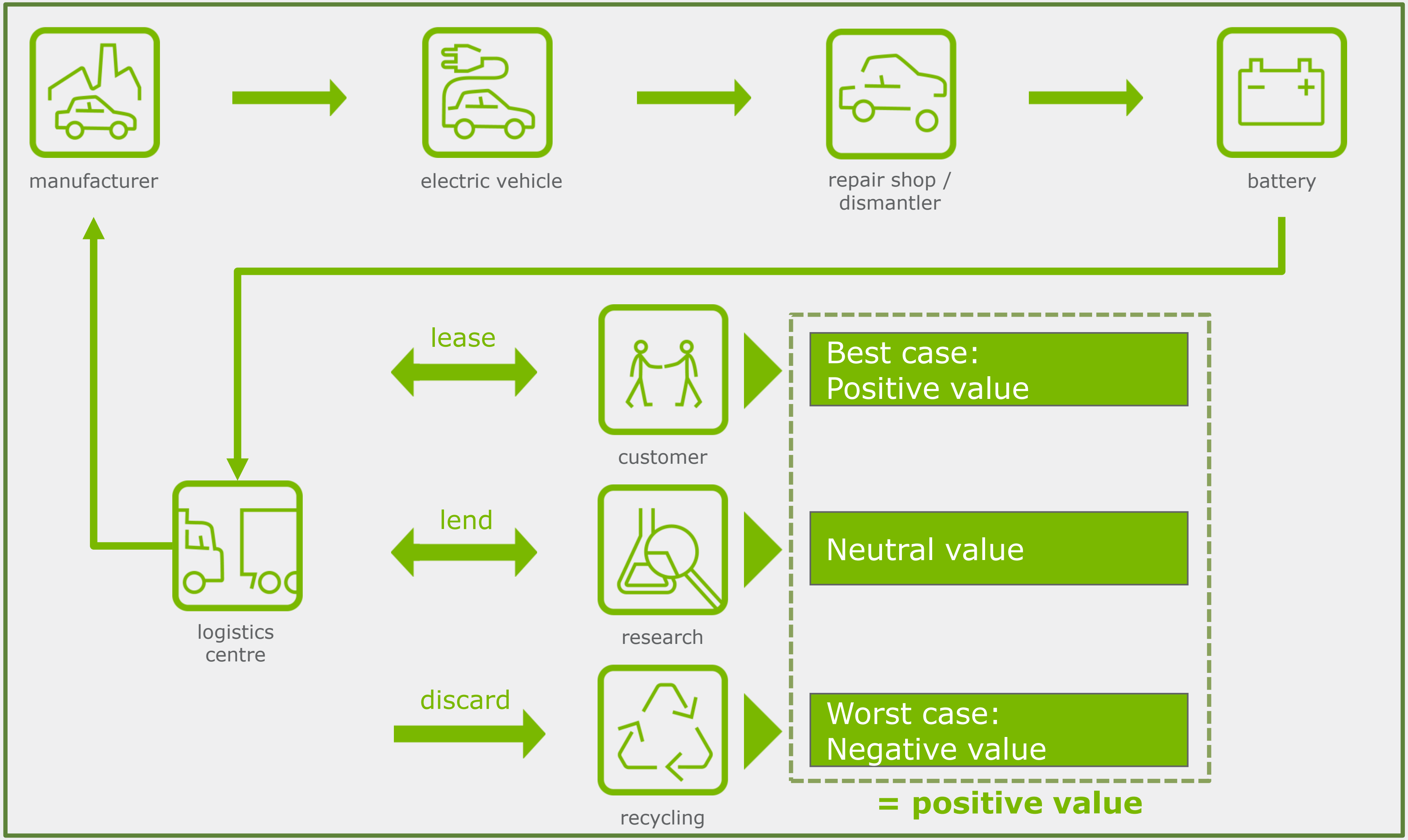
– Potential for large scale commercial reuse of batteries to generate funds

– Many manufacturers want their batteries returned in the correct order

– Recycling operations are already transnational

ARN

Reuse plan



ARN

Conclusions: approach to *extend* the life cycle

- Mitigating possible recycling cost by finding commercial reuse potential for batteries

- Using existing knowledge and synergies within ARN, partner networks and knowledge/expertise of manufacturers

- Helping to pave the road towards 100% ‘green’ electric vehicles

ARN