What is a “sustainable development”? - a material perspective

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GRANTA
TEACHING RESOURCES

This lecture unit is part of a set created by Mike Ashby to help introduce students to materials, processes and rational selection.

The Teaching Resources website aims to support teaching of materials-related courses in Design, Engineering and Science.
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Fuel efficient, but sustainable?

Safe, but sustainable?

SUSTAINABILITY ?

- *Energy*
- *Materials*
- *Environment*
- *Emissions*
- *Safety*
- *Legality*
- *Social acceptance*
- *Space*
- *Economics*

What is this talk about?

Mission statement

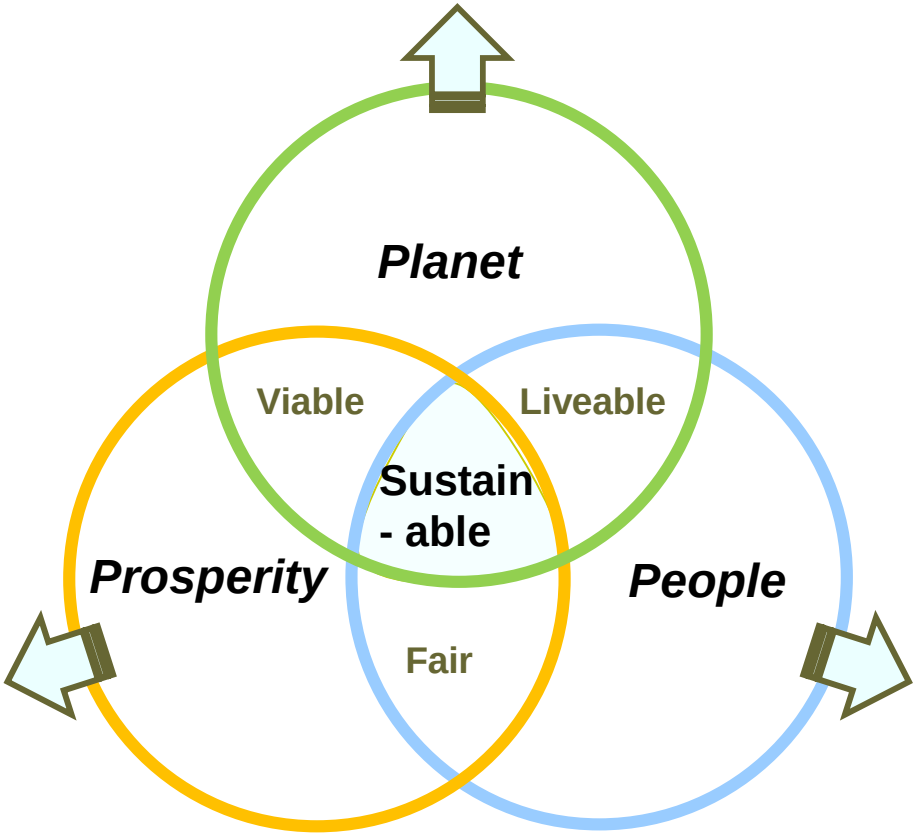
Provide framework for critical, independent assessment of "Sustainable Developments"

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

Report of the Brundtland commission of the UN, 1987

- ***But how?***
- ***And where do materials fit in?***

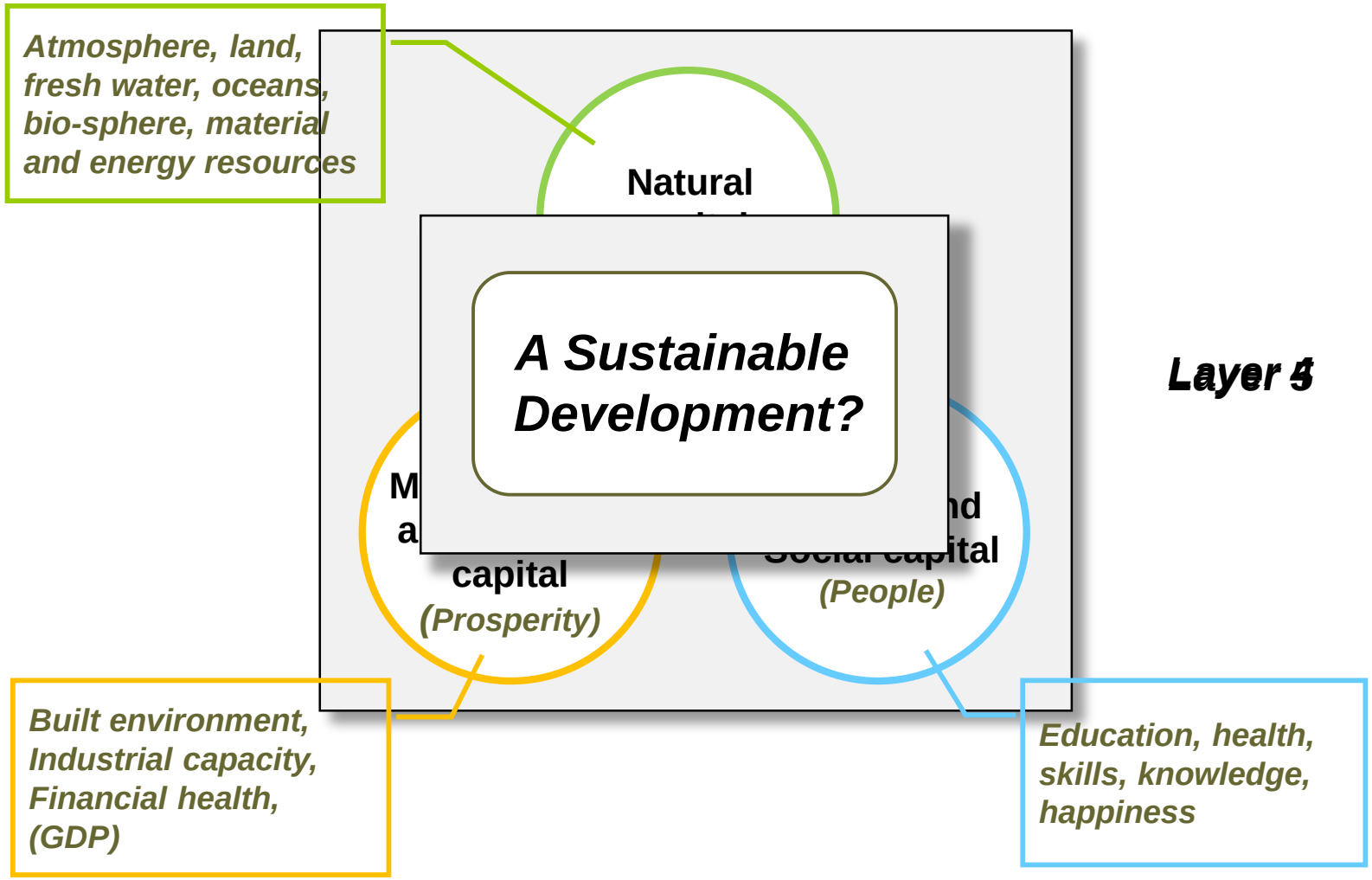
Triple Bottom Line accounting



Corporate sustainability report (SR):

- ***Financial bottom line***
- ***Social / ethical performance***
- ***Environmental performance***

Macro-economic view: the Three Capitals



Layer 4

“Articulations” of sustainable development

Motivation *(Prime objective)*	Articulation	Size and time scale
▪ *Reduce dependence on oil*	Bio-polymers	*20% of all polymer production by 2025*
▪ Stimulate low-carbon economy	Carbon taxes	€ 40 per tonne by 2030
▪ Stimulate circular materials economy	Mandatory car recycling	85% recycled by 2015

Each articulation has a

- ***Objective***
- ***Size scale***
- ***Time scale***

Layer 1

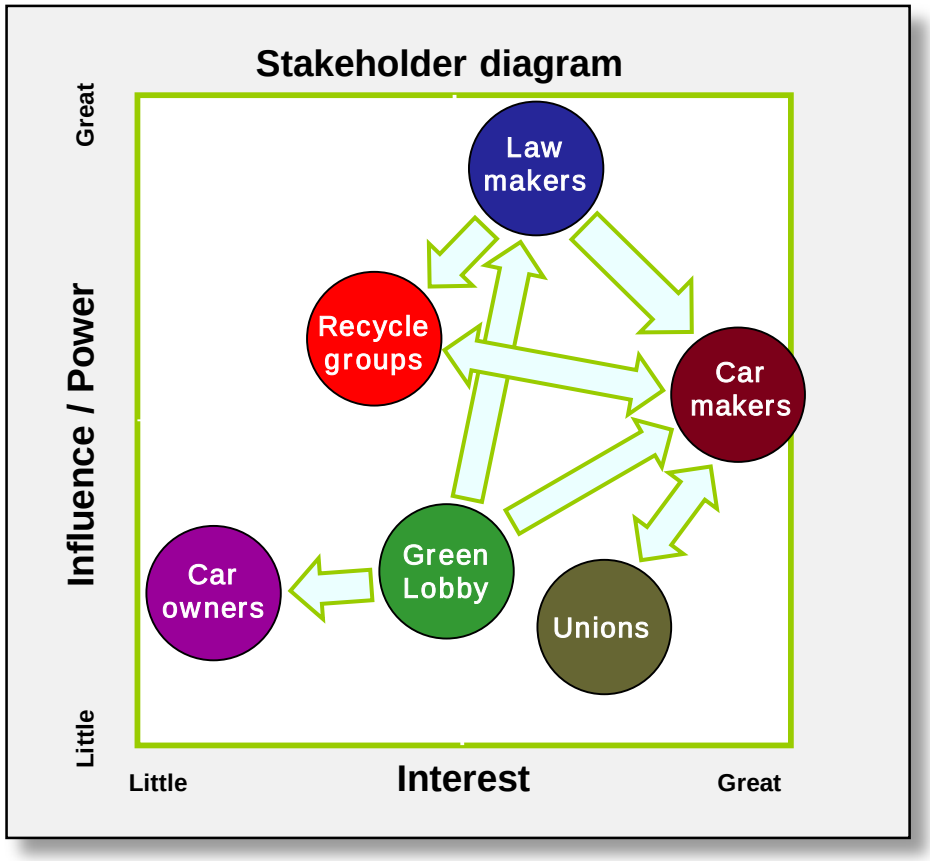
The context: Stakeholders

Stakeholders

- *Who are they?*
- *What are their concerns?*
- *What power do they have?*

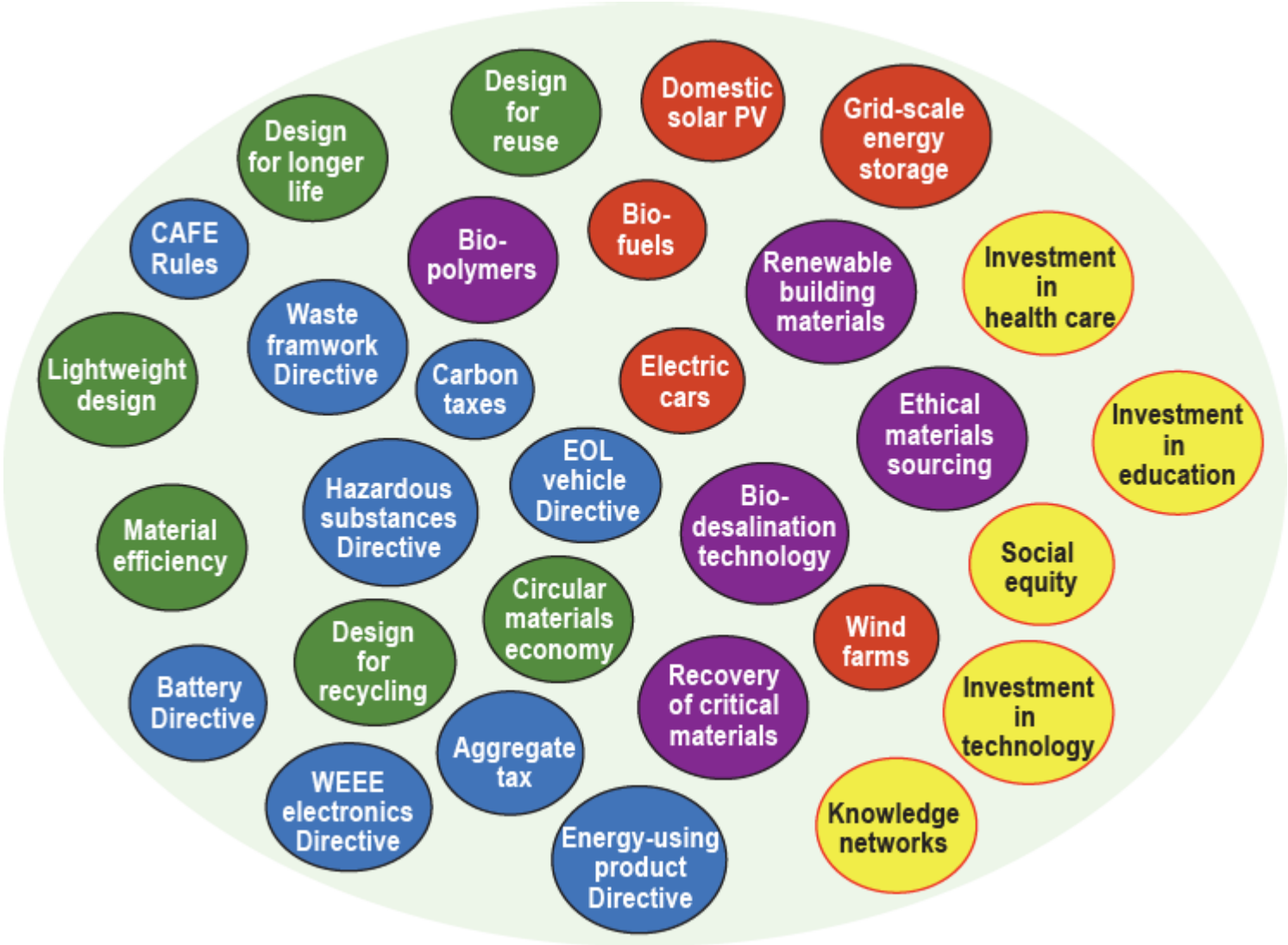
- *Government*
- *The public*
- *Local communities*
- *Owners*
- *Manufacturers*
- *Suppliers*
- *Trade Unions*
- *Customers*
- *Lobbyists*
- *Investors*
- *National press*
- *Managers, colleagues, team*

Mandatory recycling of cars



Layer 2

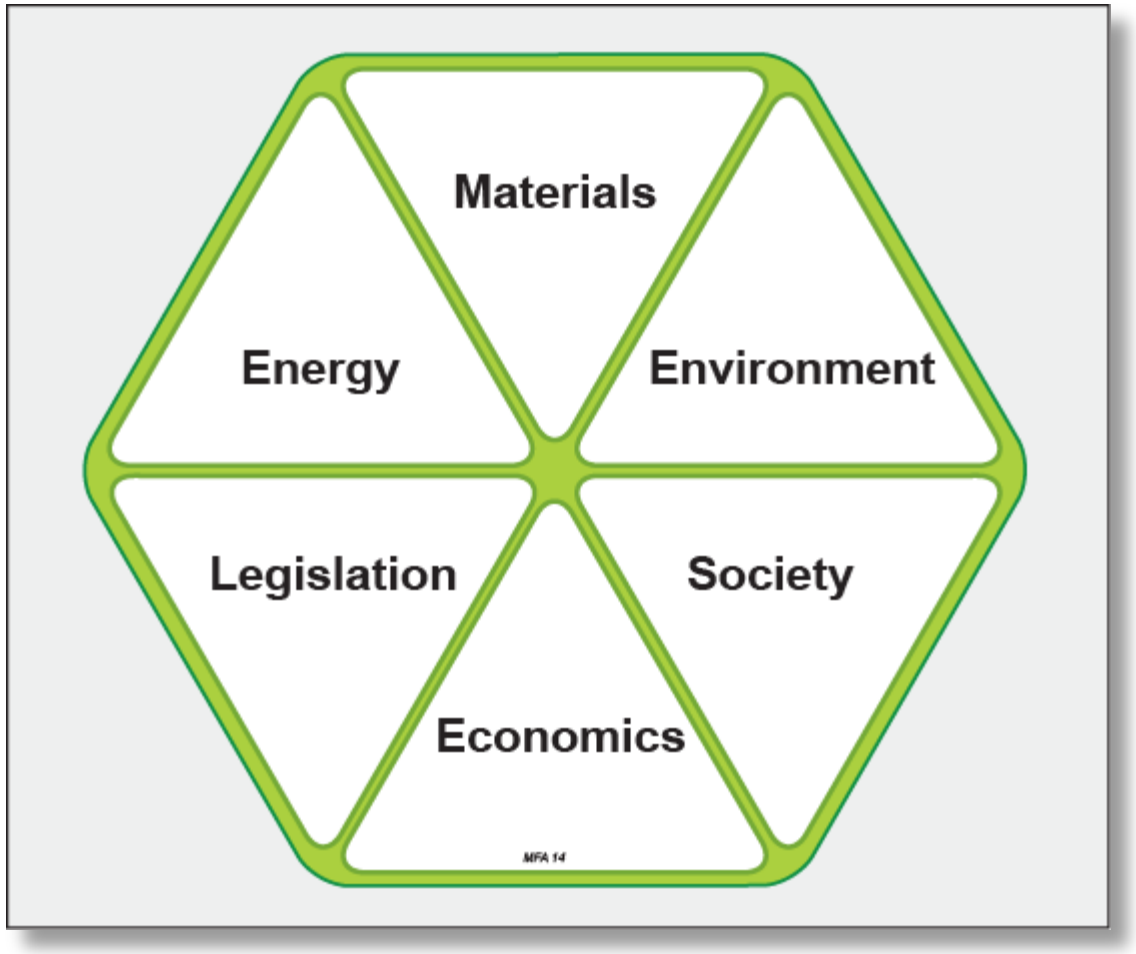
Map of Articulations



What do we learn? Group under

- Materials
- Environment
- Energy
- Legislation
- Society
- Economics

Analysing an “articulation”



Layer 3

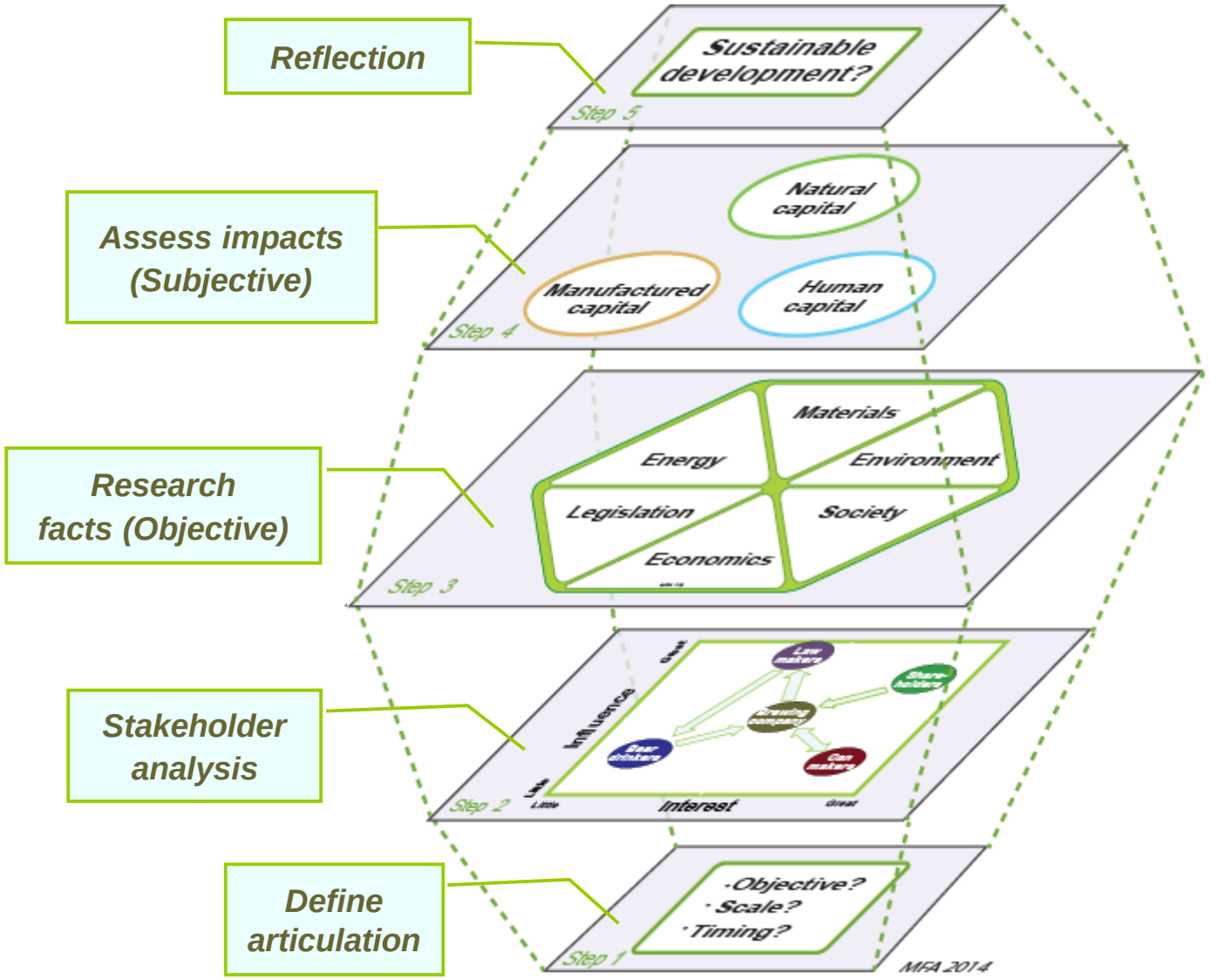
Material-efficient design

Resource-efficient design

Eco-design

Sustainable design

Analysing an “articulation”



5-step method

1. Objective
2. Stakeholders
3. Fact-finding
4. Debate impact
5. Reflect

Case studies

Biopolymers

Electric cars

Bamboo flooring

Lighting

Solar PV

Wind farms

Step 1: The articulation, the objective, the scale

Articulation **10% of all car production to be electric by 2020**

(Governments targets in US and Europe in 2012)

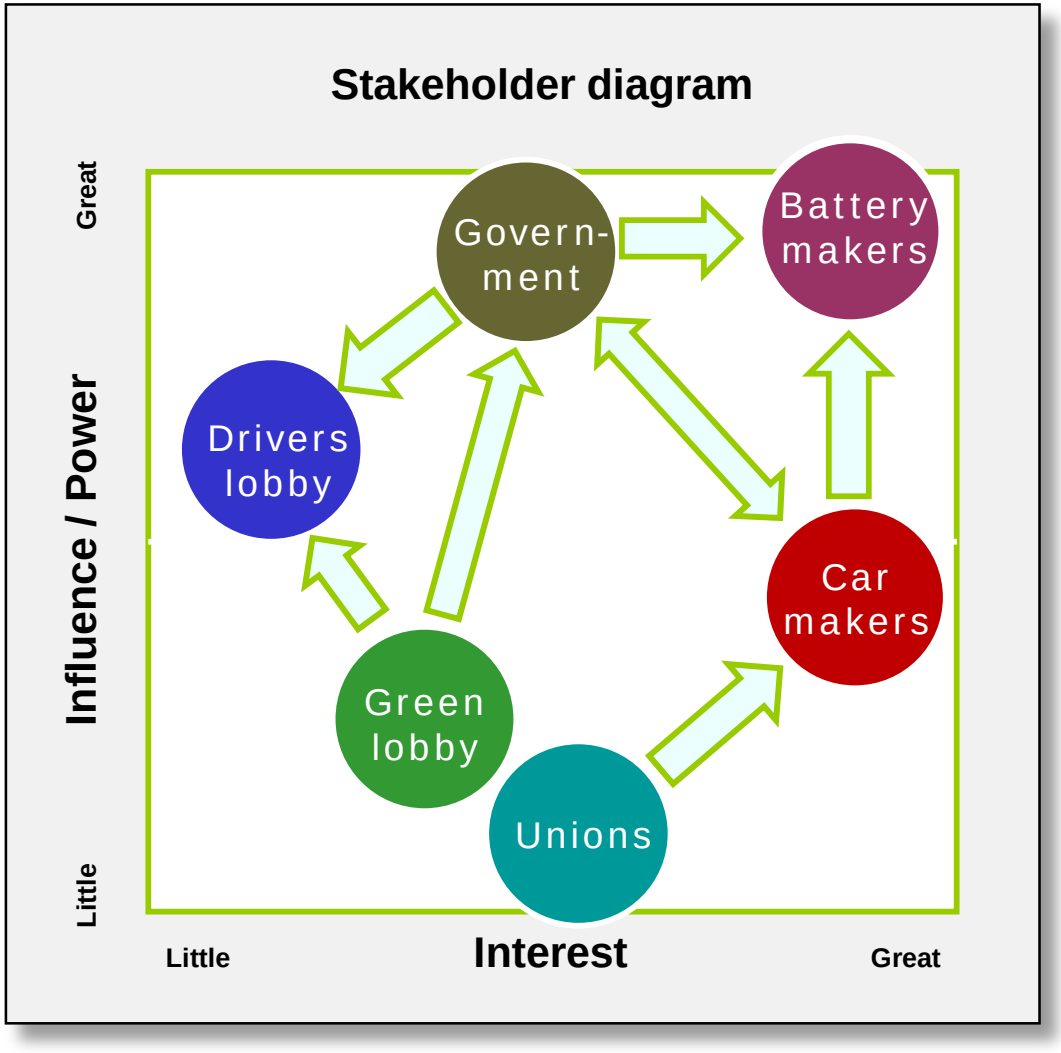
Prime objective **Decarbonize road transport**

Scale **8 million e-cars / year by 2020**

Layer 1

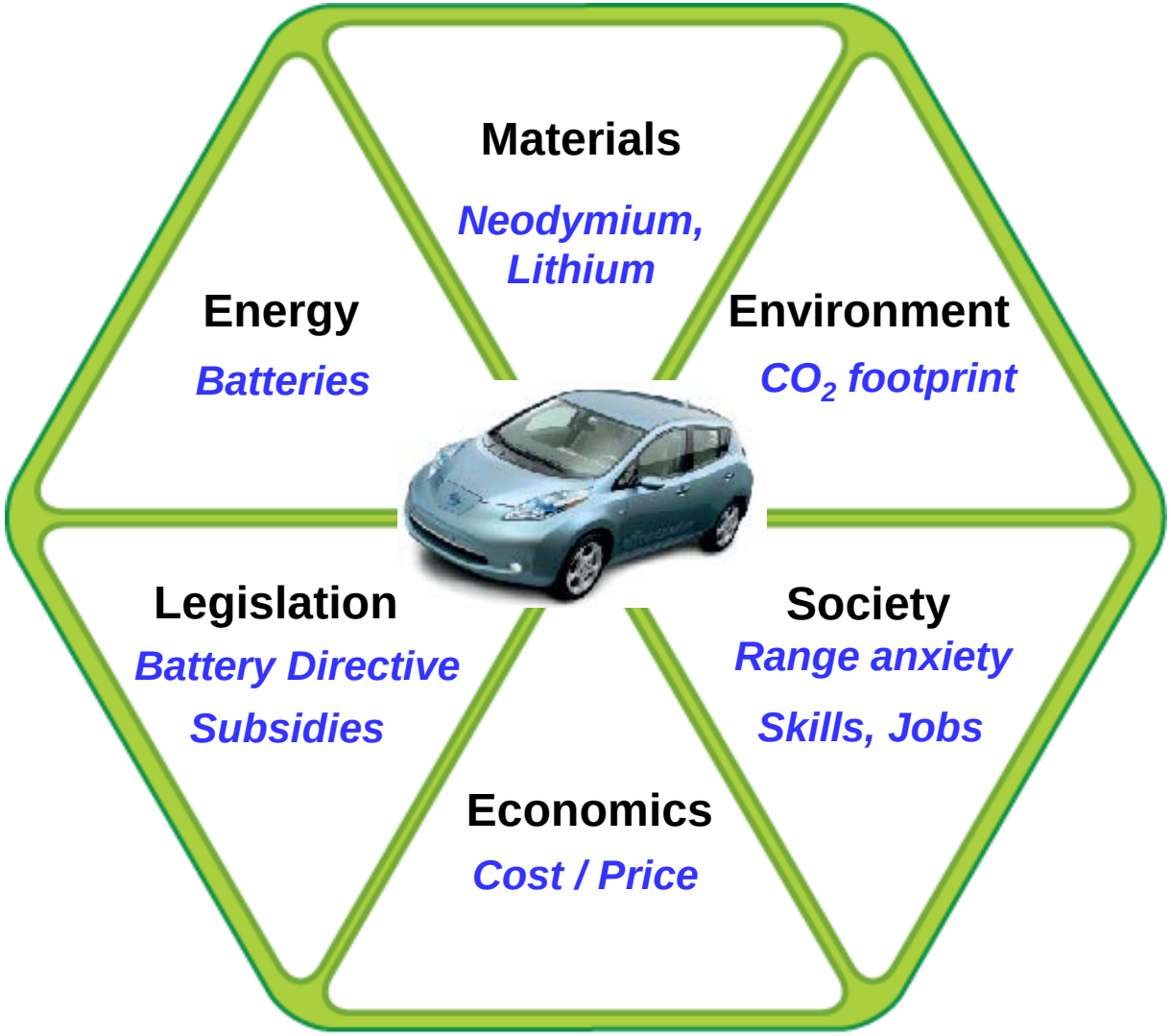
Step 2: Stakeholders and concerns

- **National and local government**
  – *carbon targets*
- **Car makers and distributors**
  – *sales*
- **Battery makers**
  – *Supply chain, recycling*
- **Labor Unions**
  – *employment, rights*
- **Drivers, Automobile Associations**
  – *range anxiety, cost*
- **Environmental campaigners**
  – carbon footprint



Layer 2

Step 3: Fact-finding



Fact-finding – Materials (1)

Neodymium-boron magnet rotors

8 million cars per year, 1.5 kg neodymium per car

= 12,000 tonnes per year

Rare earth production

Nation	Tonnes/yr
China	*130,000*
India	*3,000*
Brazil	*550*
Malaysia	*30*
World	**133,580**

Critical material!

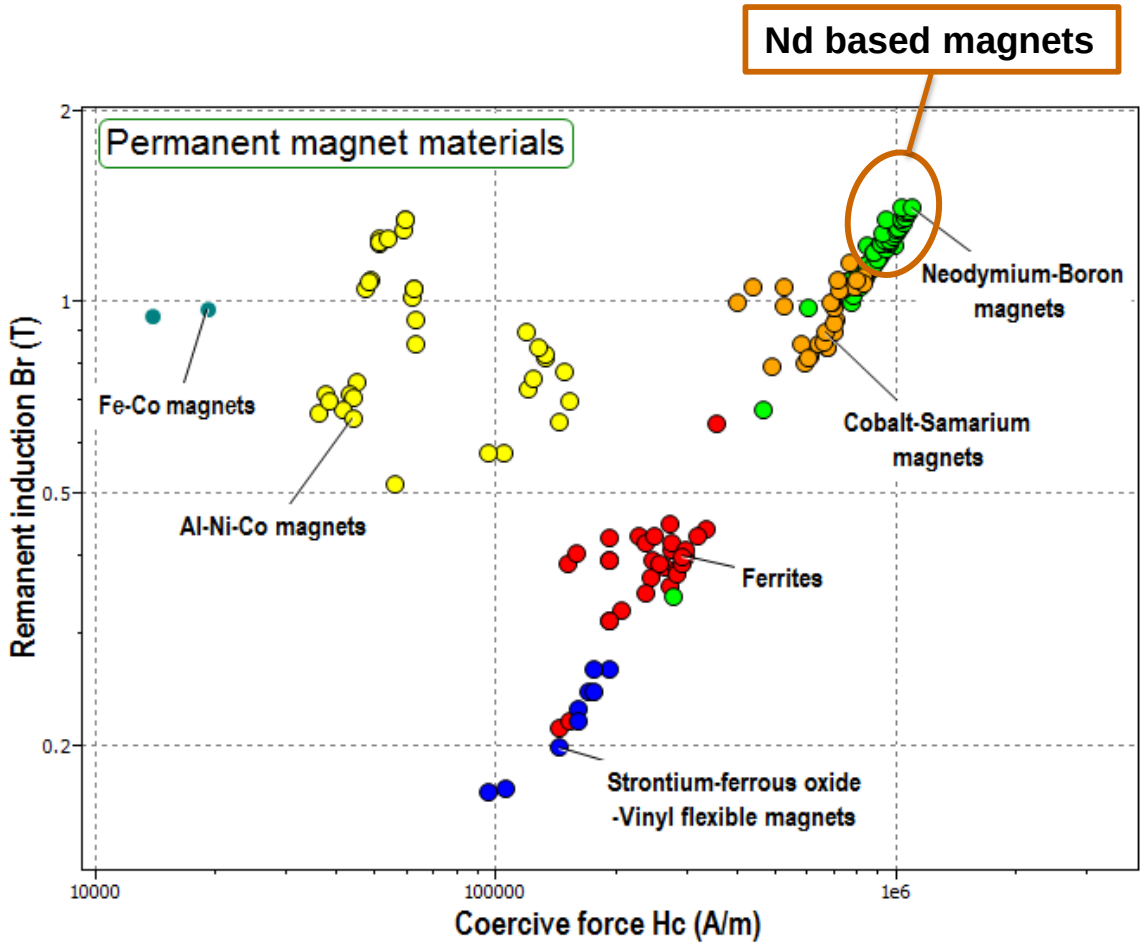
Of which 20,000 tonne is Nd

***Nd** demand = **60% of** present world production*

Fact-finding – Materials (1)

Alternative magnets?

Need high remanence and high coercive force



Fact-finding : Materials

Lithium-ion batteries

8 million cars per year, 7.3 kg Lithium per car

= 58,400 tonnes per year

Lithium production (2011)

Nation	Tonnes/year
Chile	*12,600*
Australia	*11,300*
China	*5,200*
Bolivia	*5,000*
Argentina	*3,200*
World	**34,000**

***Li** demand = **160%** present world production*

Fact-finding: Energy

Alternative batteries?

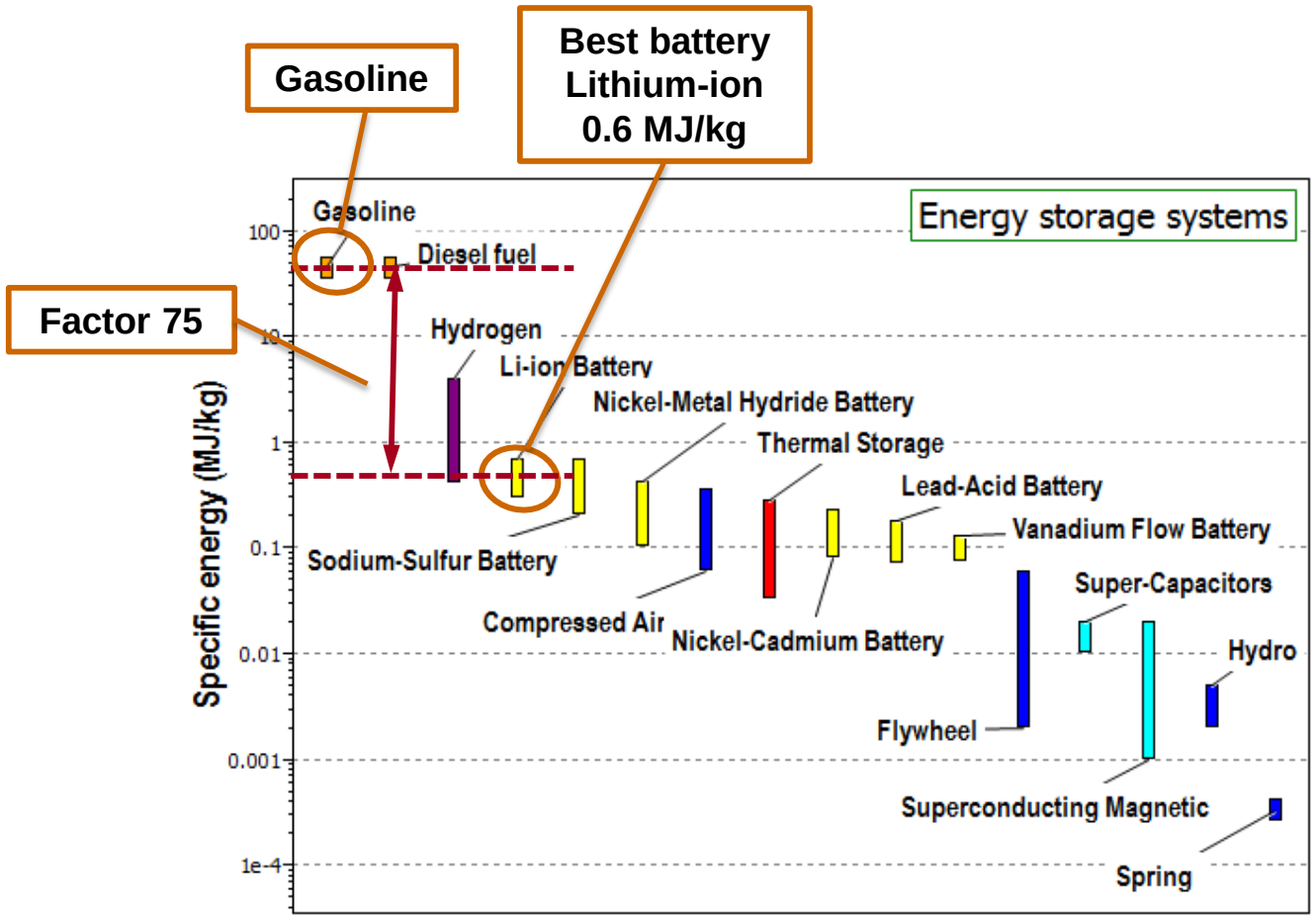
Seek high energy density (MJ/kg)

Lithium ion

Nickel metal hydride

Nickel cadmium

Lead-acid



Fact-finding: Regulation

- **US CAFE Standard** – ***Fleet mileage standard***
- **EU Automotive Fuel Efficiency Standard** – ***Fleet mileage standard***
- **EU End-of-Life Vehicles Directive** – ***85% recycled by 2015***
- **EU Battery Directive** – ***No batteries to landfill***

Environment: Can Prime Objective be met?

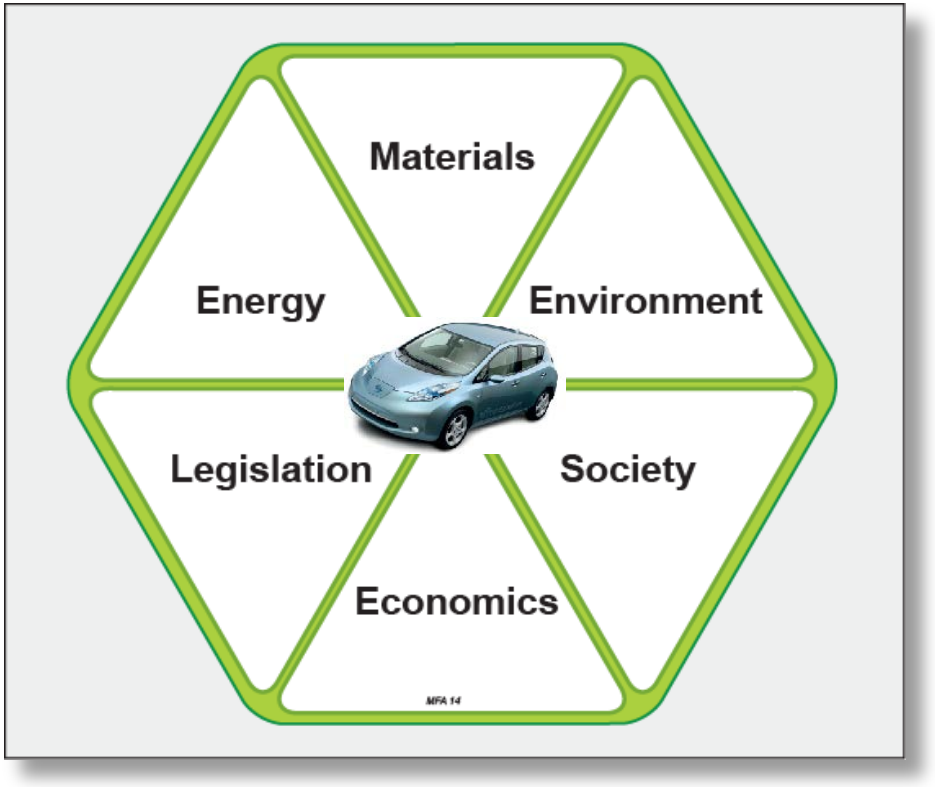
Decarbonize road transport?

Charge vehicle from the National Grid, gas / coal fired.

- **CO_2 footprint, gas fired power ≈ 140 g / MJ**
- **Delivered energy to propel small car ≈ 0.6 MJ / km**
- **Efficiency of battery – electric motor set ≈ 85%**
- **Carbon footprint of electric car ≈ 140 x 0.6 / 0.85**

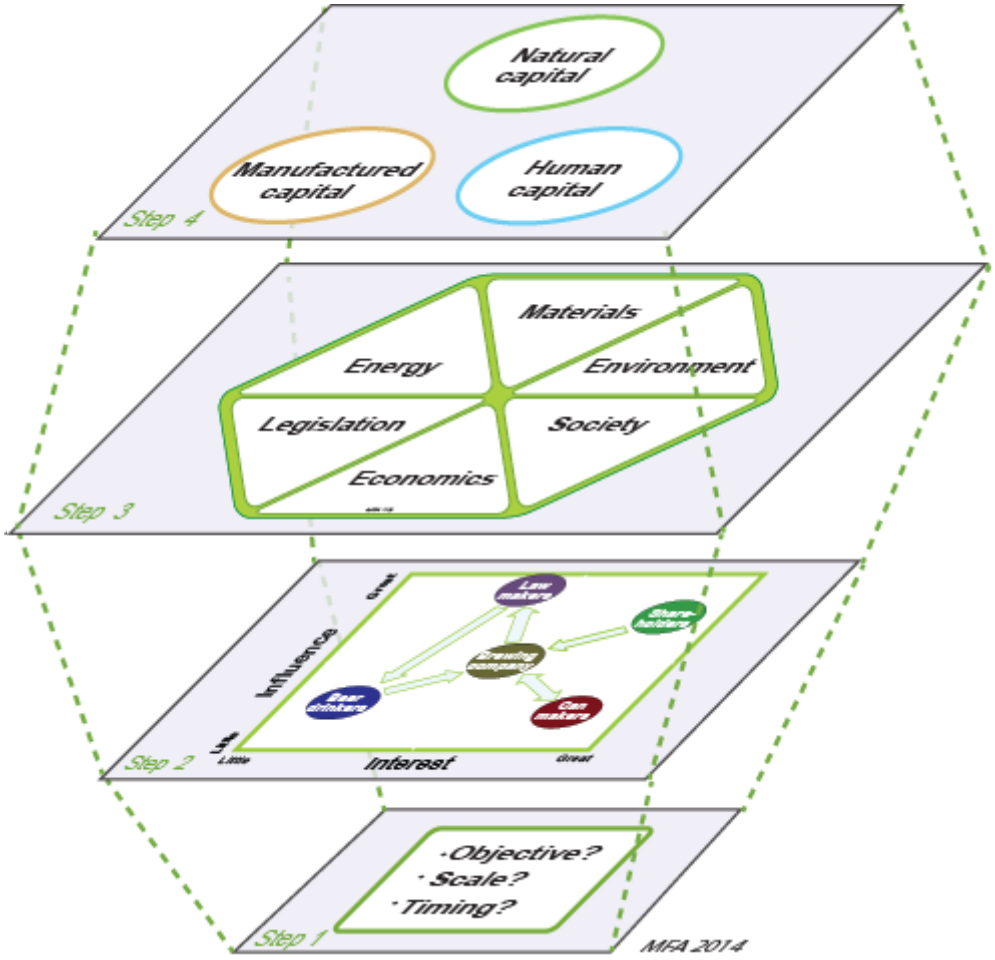
  ≈ 100 g / km

Goal of Stage 3



Layer 3

Analysing an “articulation”

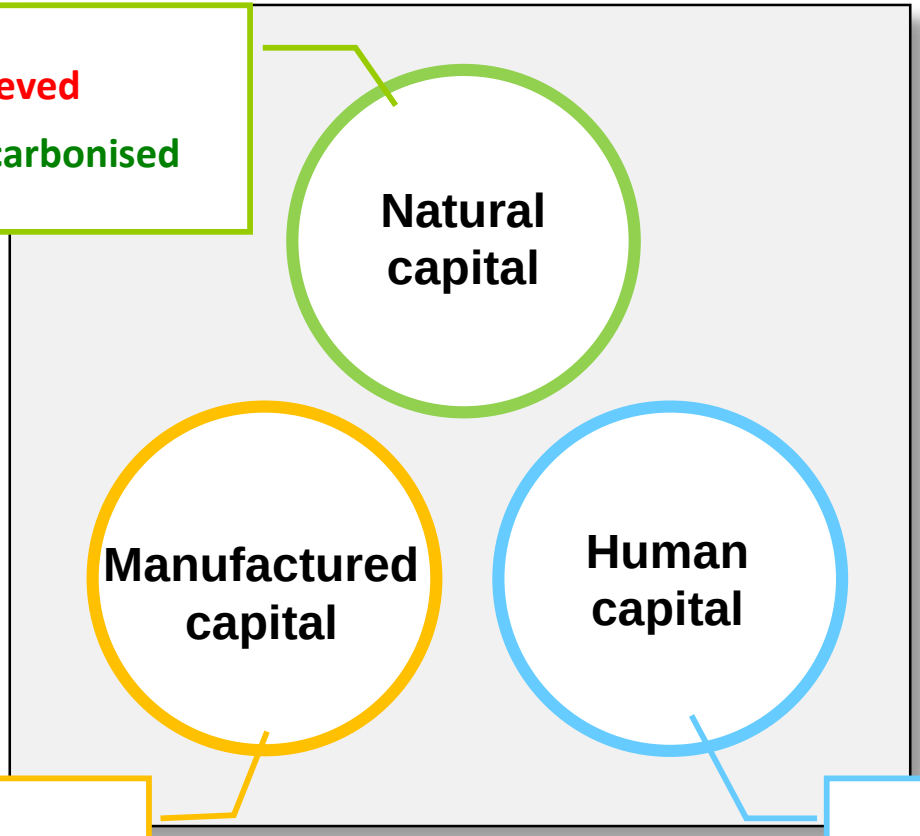


Step 4: Impact on the Three Capitals: details

	Human and social capital - People Health? Wellbeing? Convenience? Culture? Tradition? Associations? Perceptions? Contributes to equality? Morality?	**Natural capital - Planet** *Can prime objective be met? Are stakeholder concerns addressed? Are there unwanted consequences*	**Manufactured capital - Prosperity** Cost – Benefit? (Cost facts vs. Eco facts) Legitimacy? (Conformity with law)
Materials	(–) Creates dependence on rare-earth and lithium-producing nations	(–) Creates demand for critical elements, notably Lithium and Neodymium, in kg-quantities per car (+) Use of Li and Nd in kg-scale components makes collection for recycling easier	(–) Requirement to create recycling infrastructure for lithium- and rare-earth elements
Energy	(+) Could reduce dependence of imported fossil fuels in oil-poor nations	(–) Very little contribution to carbon emissions unless national grid is decarbonized	(+) Creates employment in energy sector (–) Need for to additional power stations (–) Need for investment in recharging point
Environment	(+) Reduces emission levels in large cities	(+) Offers potential for clean energy for transport	–
Legislation	(+) Helps meet the nation's commitments to reduce emissions	(+) Take-back and recycling legislation reduces waste stream, contribute to a circular economy	(–) Meeting end-of-life regulations creates additional costs
Economics	(–) Need to subsidize sales of electric cars adds becomes a "green" tax.		(–) Profitability uncertain without government subsidies (–) Large capital investment in new electricity generating plant to provide for charging
Society	(+) Satisfaction in using an "emission-free" transport (–) Range anxiety (–) Paucity of charging points		(+) Creates employment in high-tech industry (+) Creates jobs, stimulates local industry
Synthesis (the most telling facts)	(+) Satisfaction reducing environmental impact (–) Dissatisfaction with green taxes used to subsidize green transport	(+) Ultimate success dependent on new battery technology , decarbonized grid and adaptation to range limitations – impossible in short term (+) But potentially possible in the long term.	(–) Electric cars not, at present, economic . Many issues to be resolved to make it so.

Step 4: Impact on the Three Capitals

- Objective not achieved
- Possible if grid decarbonised

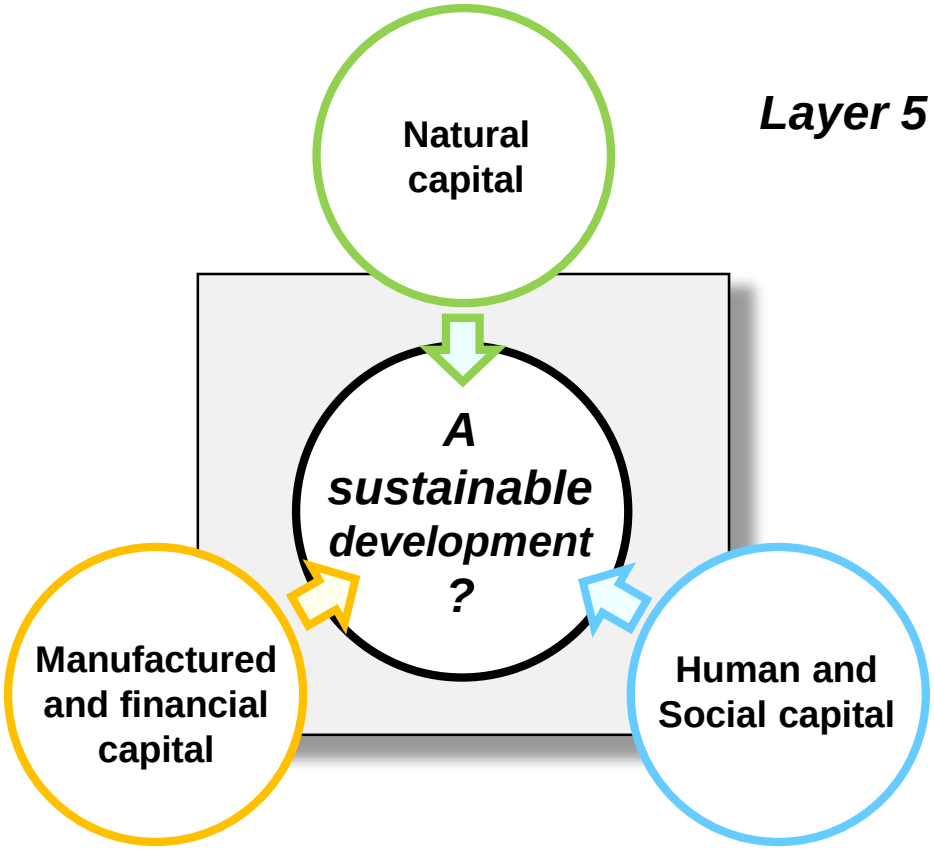


Layer 4

- Supply chain for Li in doubt
- Expanded Li production

- Range anxiety not met
- Battery development

Step 5 – Reflection



Layer 5

Short term – 7 years

- ***Not on envisaged scale and time***

Long term – 25 years

- **Establish infrastructure**
  - **supply chain**
  - **recycling capacity**

Was the objective right?

Alternative strategies?

Related Projects

Electric buses and Electric bikes

- Different objectives
- Different scale
- Different stakeholders
- Different facts
- Different impacts on the 3 capitals

So what?

- **No completely “right” answer to questions of Sustainability**
- **Instead, an thoughtful, well-researched response recognising the conflicting facts, seeking best compromise**
- **Layer-based approach provides a framework – assembling the pieces in simple, progressive way**

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