THE UNIVERSITY OF AUCKLAND

FACULTY OF ENGINEERING

Design for Sustainable Development

A Framework for Sustainable Product Development and its Application to Earthmoving Equipment

Jeff Vickers (Presenter) & Dr Carol Boyle, 1 December 2010

Department of Civil & Environmental Engineering
University of Auckland, New Zealand

Overview

- Background to (eco-)innovation
- The Design for Sustainable Development (DfSD) Framework
- Introducing the case study: earthmoving equipment for construction aggregates
- Applying the framework to the case study

BACKGROUND:
(ECO-)INNOVATION

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1 December 2010

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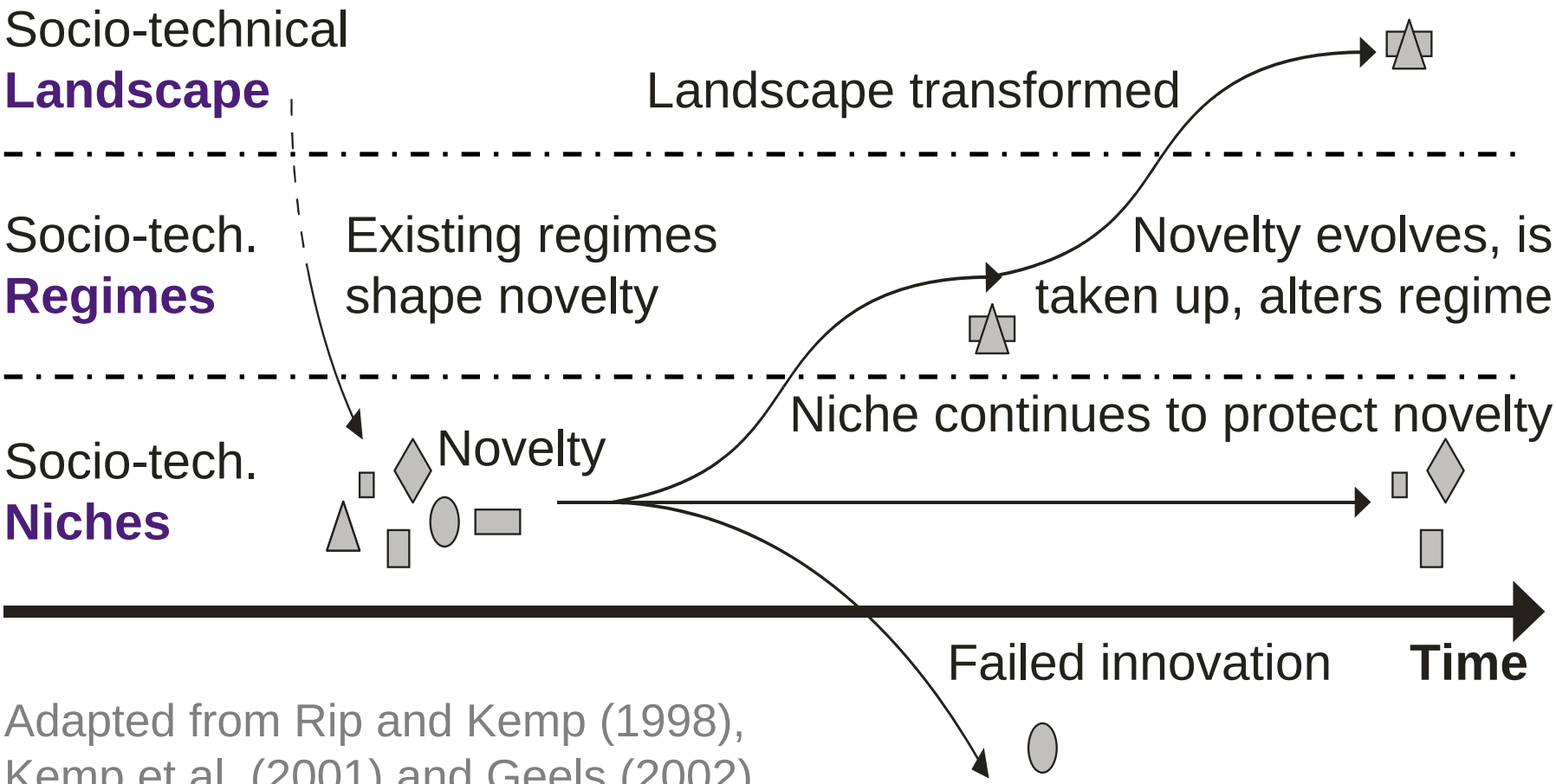
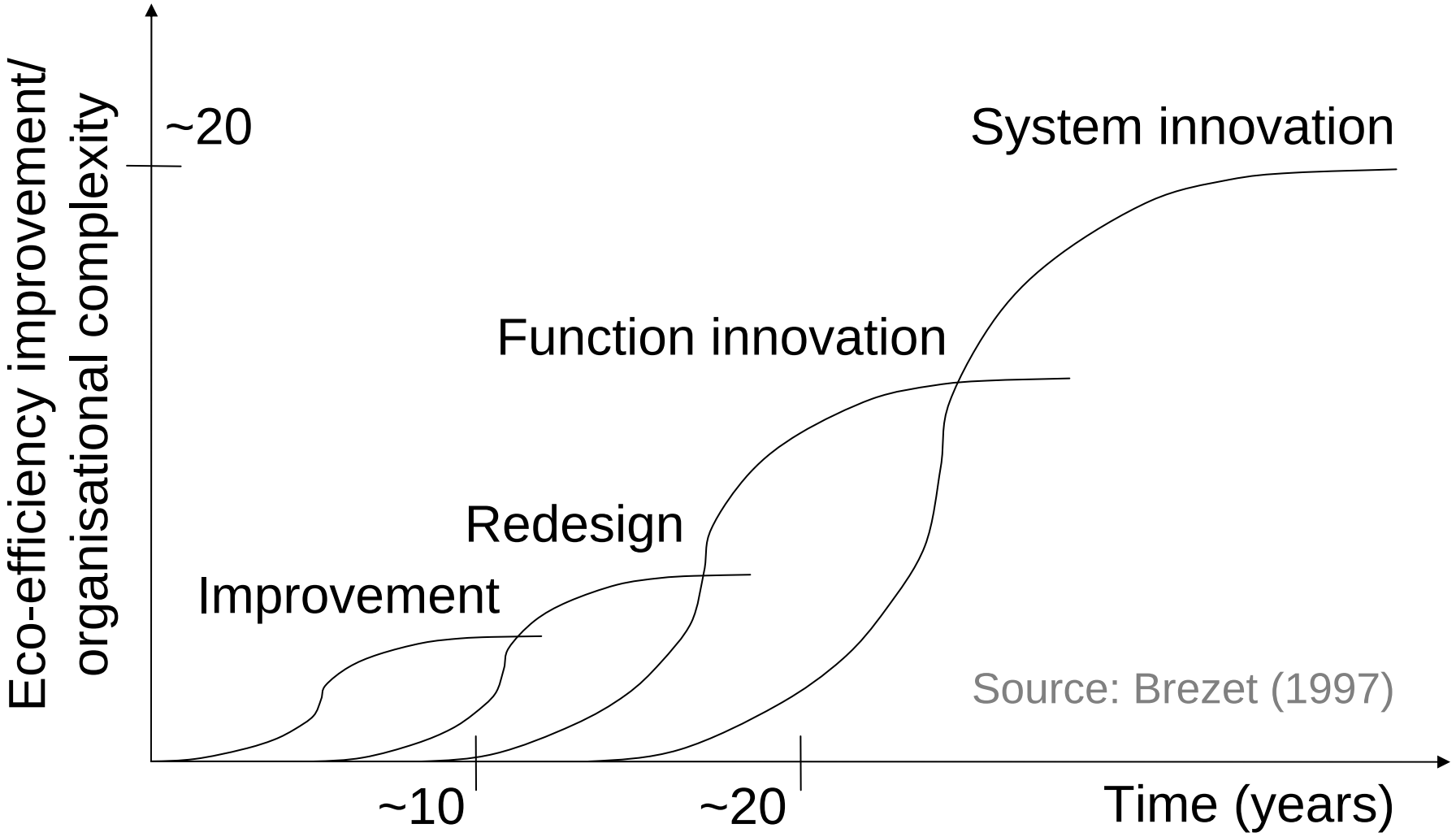
An evolutionary view of innovation



Adapted from Rip and Kemp (1998), Kemp et al. (2001) and Geels (2002)

Levels of eco-efficiency improvement



DESIGN FOR SUSTAINABLE DEVELOPMENT, **DfSD FRAMEWORK**

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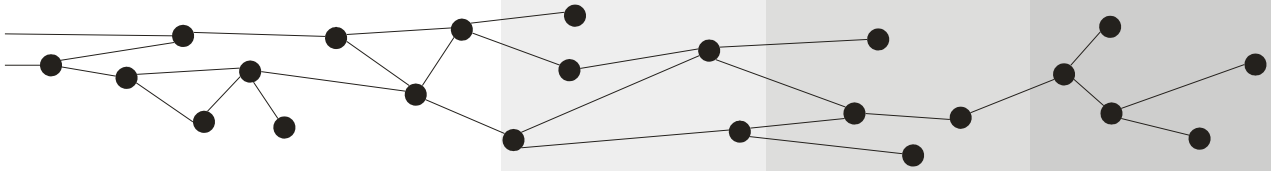
STRATEGIC

Scenario network map(s) for current and possible future markets



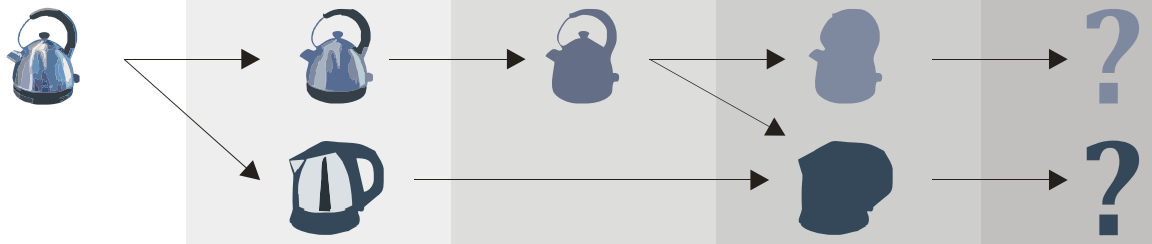
[where ● = event]

Market-level opportunities and threats

Product/service/organisational concepts

TACTICAL

Product/service/ organisational roadmap(s)

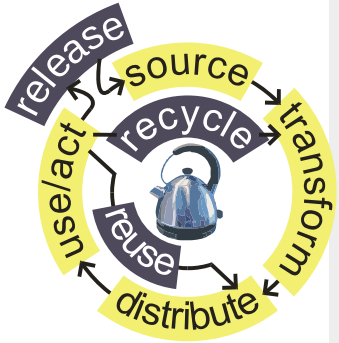


Specification (incl. stricter social-ecological performance criteria)

Product/service/organisational possibilities

OPERATIONAL

Benchmark and optimise social-ecological performance across the entire product/service life cycle



Examples of product optimisation strategies

source	supplier audits	release	reduce toxics
transform	reduce scrap	reuse	swappable parts
distribute	airplane » ship	recycle	material labels
use/act	automatic power-save mode		

Time Today 20 years

Methodology: bottom-up (operational)

1. Benchmark current product/service across its whole life cycle (e.g. using LCA)
2. Identify “hot spots” for improvement
3. Incrementally improve environmental and social performance, focusing on the hot spots first (e.g. using eco-design)

Methodology: top-down (strategic)

1. Identify function(s)
2. Identify market(s) for function(s)
3. Frame the question for scenario-building
4. Identify stakeholders to participate
5. Build scenarios using workshops/interviews
6. Conceptualise new products/services
7. Assess relative robustness and flexibility of concepts under all scenarios
8. Roadmap development of chosen concept

INTRODUCING THE CASE STUDY
EARTHMOVING EQUIPMENT FOR CONSTRUCTION AGGREGATES

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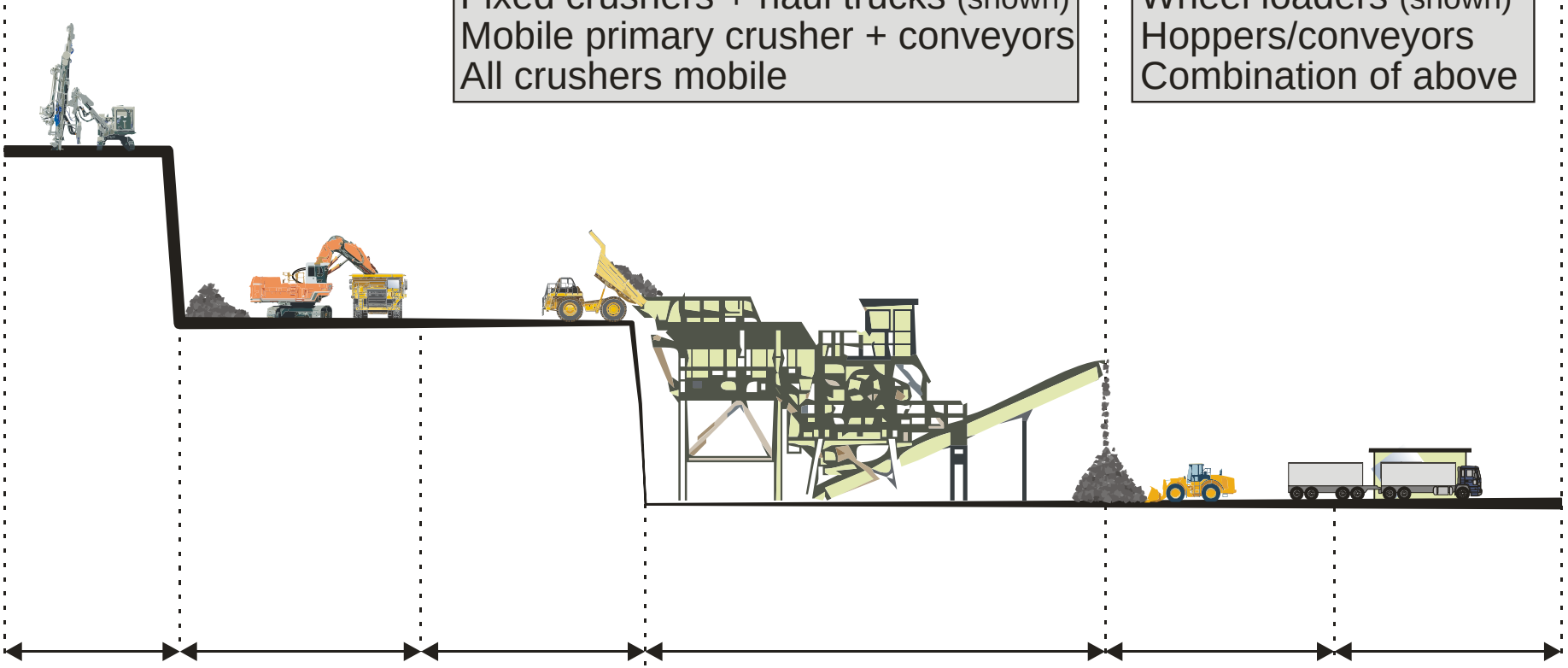
KOMATSU

Typical crushed stone quarry layout

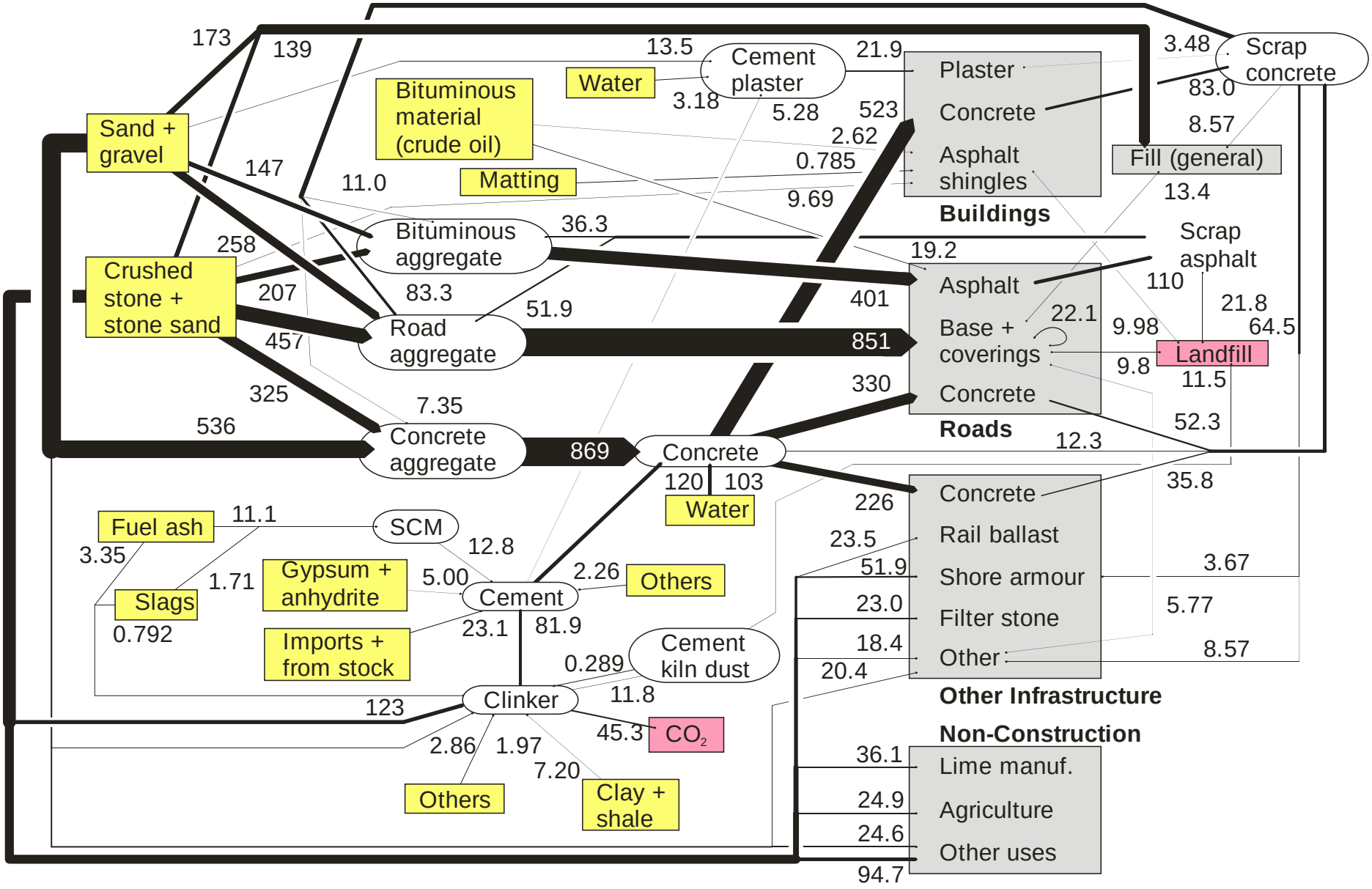
Extraction/processing variants
Fixed crushers + haul trucks (shown)
Mobile primary crusher + conveyors
All crushers mobile

Yard loading variants
Wheel loaders (shown)
Hoppers/conveyors
Combination of above



Blasting | Face loading | Off-road hauling | Crushing and screening | Yard loading | On-road hauling

Flows of construction materials



KEY: Raw material stock | Waste sink | End use (stock) | Flow within the USA in 2003 (million metric tons)

APPLYING THE DfSD FRAMEWORK

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Methodology: top-down (strategic)

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Futures of what and where?

Demolition

Waste Aggregates

Market Construction

Mining Agriculture

Manufacturing

?

Garbage trucks

Forklifts Telehandlers

Excavators **Product**

Shovels Loaders

Cranes Dump trucks

Emerging economies

Europe China

Americas **Region** Africa

Australasia Industrialised economies

India

Powertrain ICT

Tyres **Technology**

Sensors Hydraulics

For how long? 20 years?

- Long enough for “out of the box” thinking
- Time for several generations of product/ service so stricter criteria can be phased in
- Estimated time for “function innovation”
- One human generation = 20-25 years
  ∴ min. time for inter-generational thinking
- Much beyond 20 years, it becomes harder to exclude events as highly improbable

Framing a futures question

Defining a question for scenario building:

- The futures of [what?] [where?] [over what time period?]

Source: List (2005)

The question for this paper:

- The futures of earthmoving equipment in the construction aggregates industry in the industrialised world, globally until 2030

Methodology: top-down (strategic)

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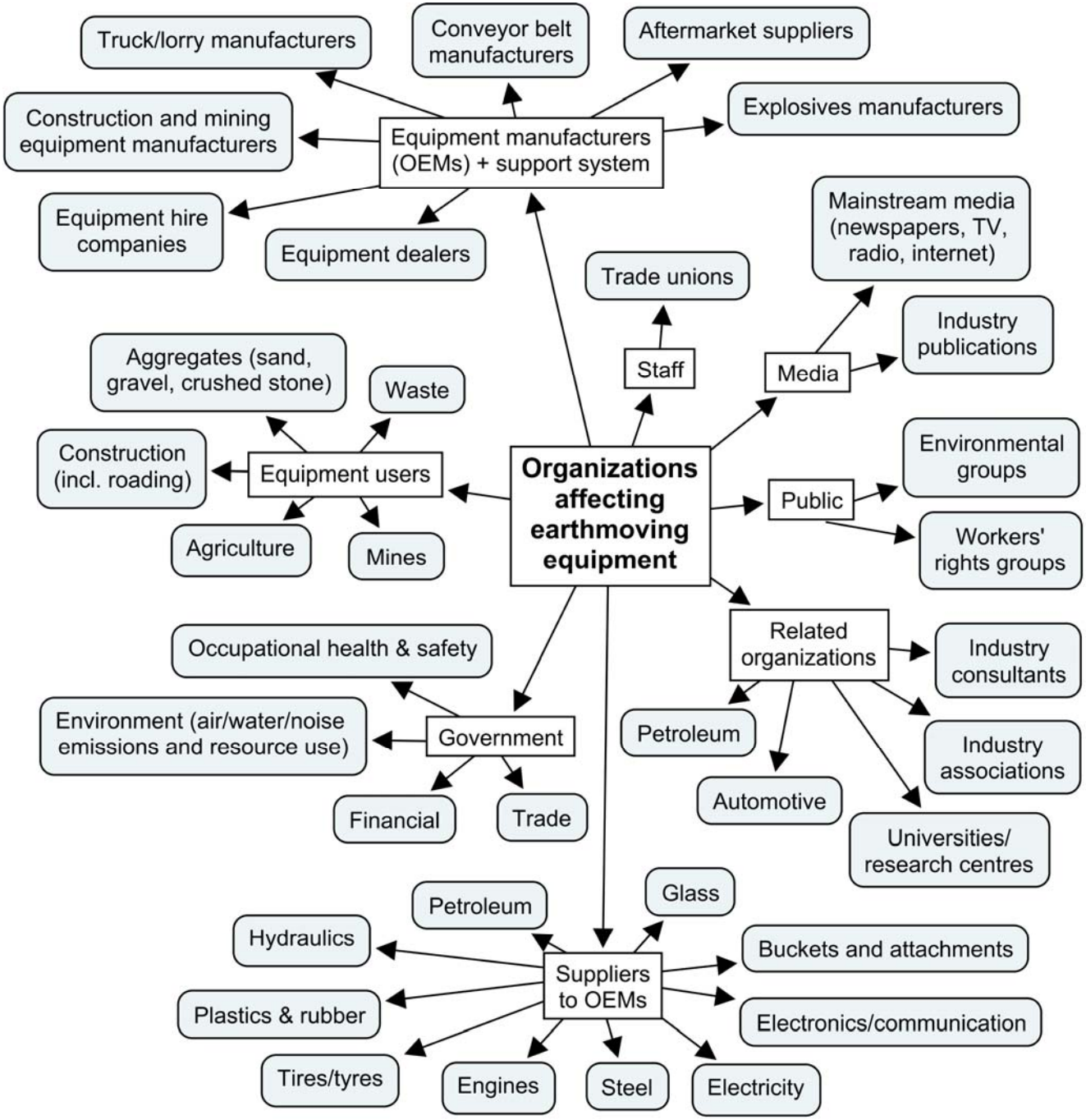
Organizations affecting earthmoving equipment
Equipment manufacturers (OEMs) + support system
Truck/lorry manufacturers
Conveyor belt manufacturers
Aftermarket suppliers
Construction and mining equipment manufacturers
Explosives manufacturers
Equipment hire companies
Equipment dealers
Staff
Trade unions
Media
Mainstream media (newspapers, TV, radio, internet)
Industry publications
Equipment users
Aggregates (sand, gravel, crushed stone)
Waste
Construction (incl. roading)
Agriculture
Mines
Public
Environmental groups
Workers' rights groups
Related organizations
Industry consultants
Industry associations
Universities/ research centres
Petroleum
Automotive
Government
Occupational health & safety
Environment (air/water/noise emissions and resource use)
Financial
Trade
Suppliers to OEMs
Petroleum
Glass
Hydraulics
Buckets and attachments
Plastics & rubber
Electronics/communication
Tires/tyres
Engines
Steel
Electricity

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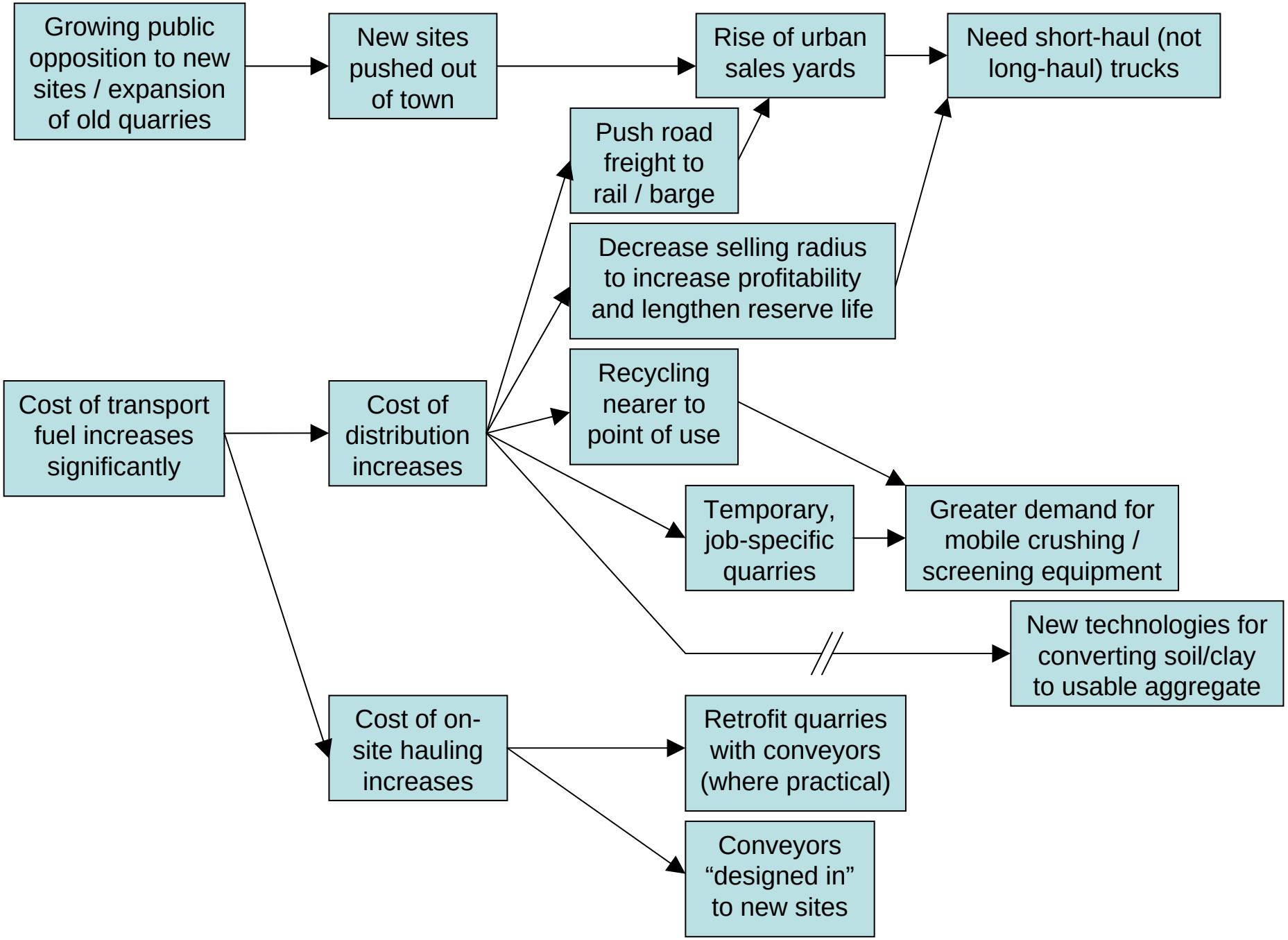
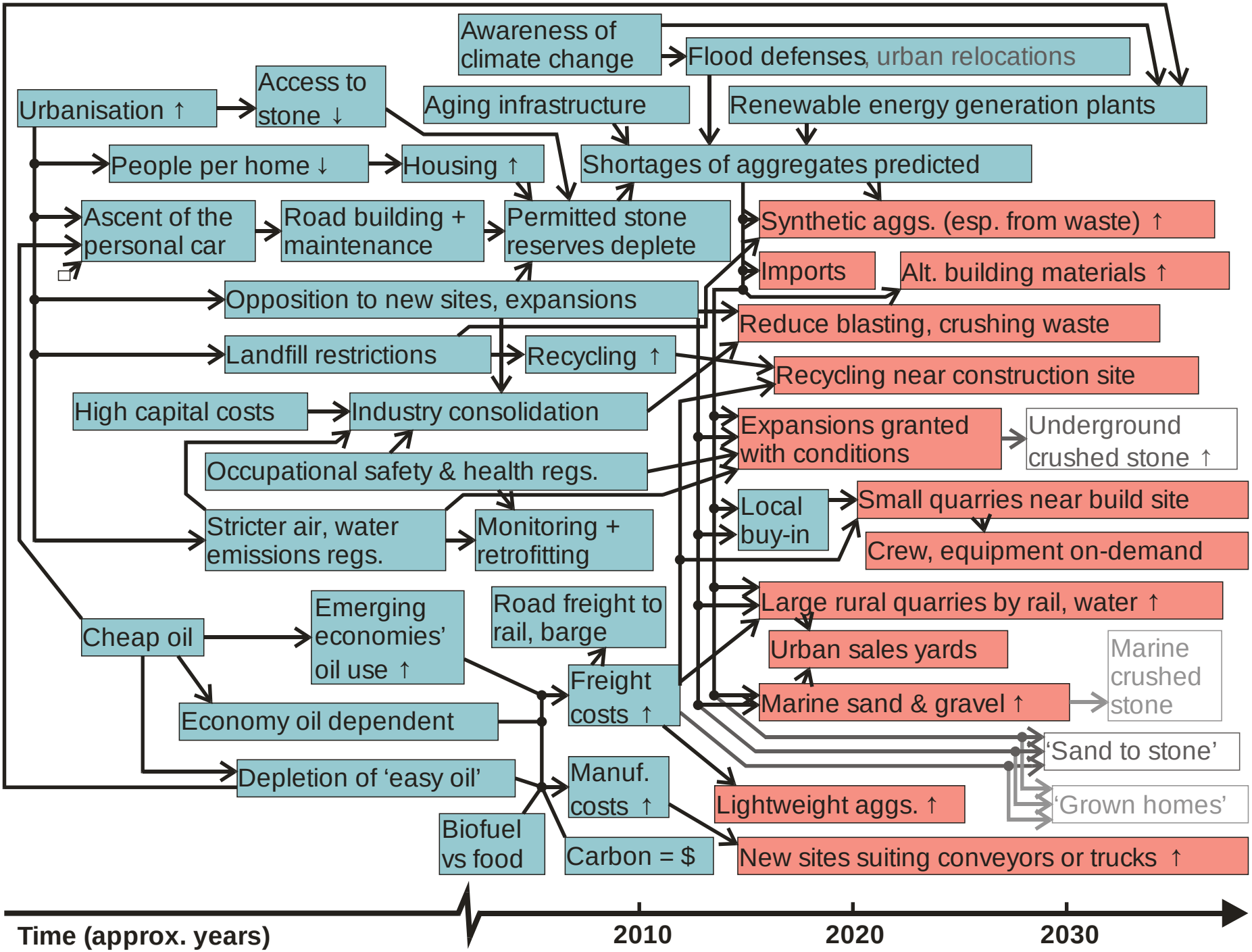

Growing public opposition to new sites / expansion of old quarries
New sites pushed out of town
Rise of urban sales yards
Need short-haul (not long-haul) trucks
Push road freight to rail / barge
Decrease selling radius to increase profitability and lengthen reserve life
Cost of transport fuel increases significantly
Cost of distribution increases
Recycling nearer to point of use
Temporary, job-specific quarries
Greater demand for mobile crushing / screening equipment
New technologies for converting soil/clay to usable aggregate
Cost of on-site hauling increases
Retrofit quarries with conveyors (where practical)
Conveyors “designed in” to new sites


Awareness of climate change
Flood defenses, urban relocations
Urbanisation ↑
Access to stone ↓
Aging infrastructure
Renewable energy generation plants
People per home ↓
Housing ↑
Shortages of aggregates predicted
Ascent of the personal car
Road building + maintenance
Permitted stone reserves deplete
Synthetic aggs. (esp. from waste) ↑
Imports
Alt. building materials ↑
Opposition to new sites, expansions
Reduce blasting, crushing waste
Landfill restrictions
Recycling ↑
Recycling near construction site
High capital costs
Industry consolidation
Expansions granted with conditions
Underground crushed stone ↑
Occupational safety & health regs.
Local buy-in
Small quarries near build site
Stricter air, water emissions regs.
Monitoring + retrofitting
Crew, equipment on-demand
Large rural quarries by rail, water ↑
Cheap oil
Emerging economies' oil use ↑
Road freight to rail, barge
Urban sales yards
Marine crushed stone
Freight costs ↑
Marine sand & gravel ↑
Economy oil dependent
'Sand to stone'
Depletion of 'easy oil'
Manuf. costs ↑
Lightweight aggs. ↑
'Grown homes'
Biofuel vs food
Carbon = $
New sites suiting conveyors or trucks ↑
Time (approx. years)
2010
2020
2030

Methodology: top-down (strategic)

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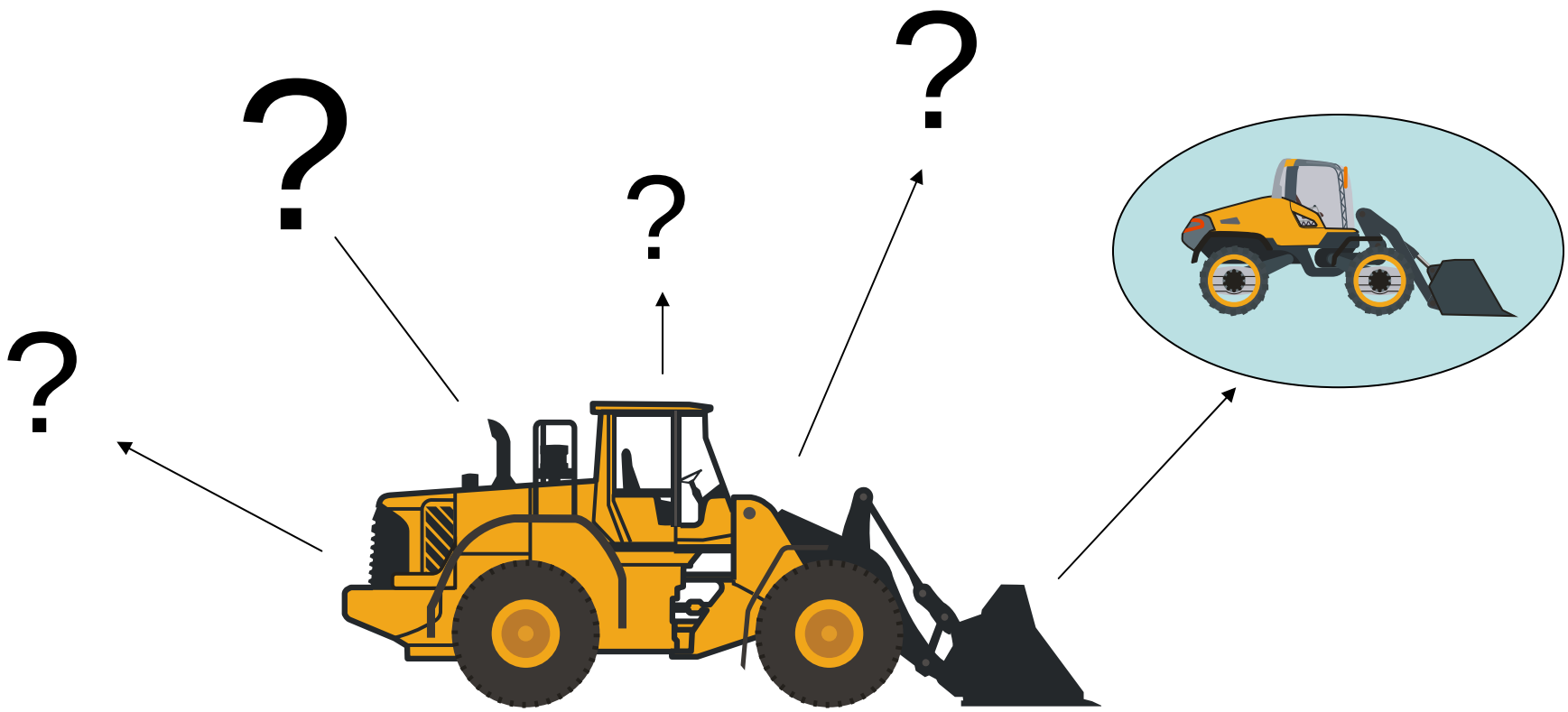
Conceptual development (1)



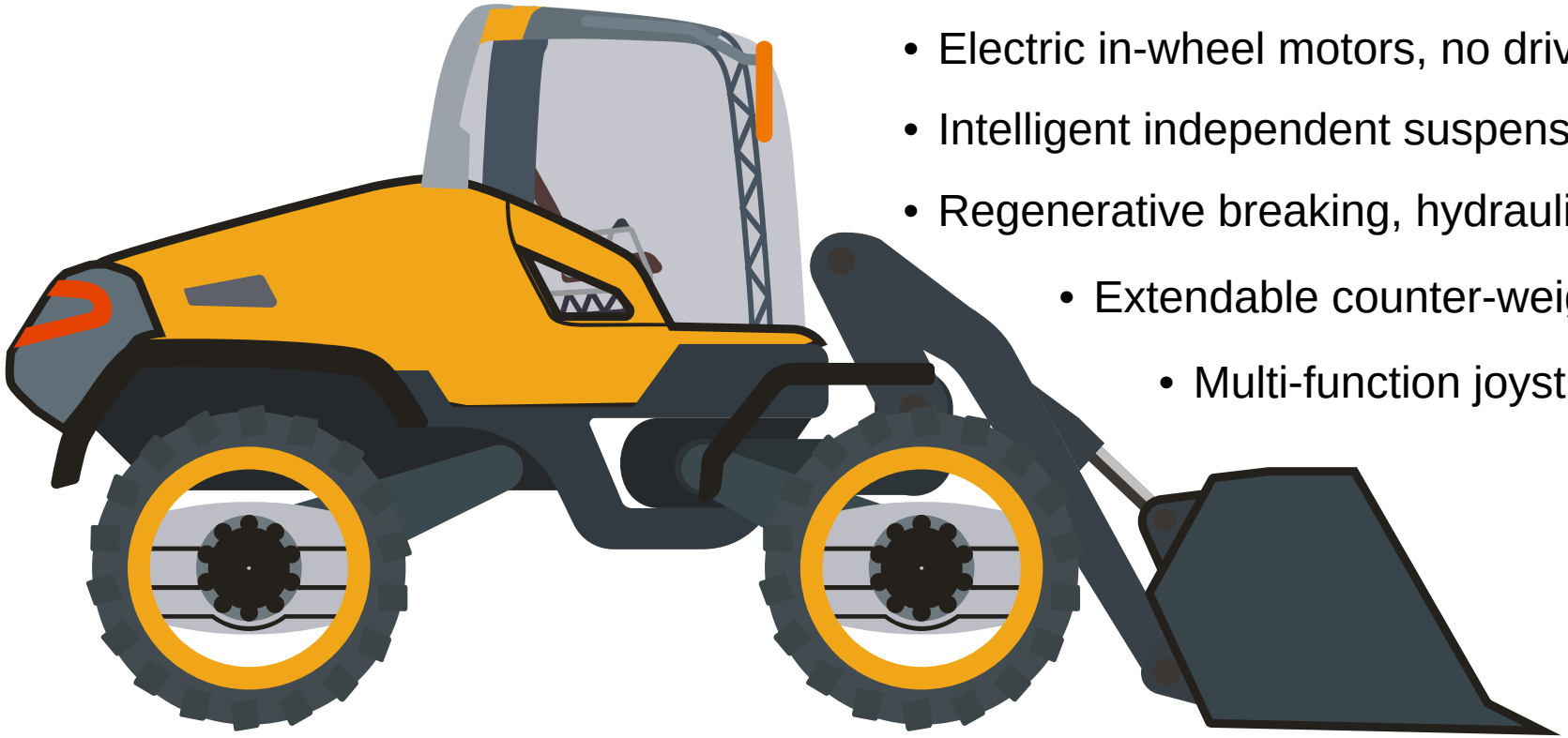
Current model since 2007

Sketch of L220F wheel loader based on Volvo CE (2007b).
Based on publicly available information. In no way endorsed by Volvo CE.

Conceptual development (2)

Wheel loader for 2025

- High visibility cab with smart glazing
- Diesel-electric hybrid engine
- Electric in-wheel motors, no driveline
- Intelligent independent suspension
- Regenerative breaking, hydraulics
- Extendable counter-weight
- Multi-function joysticks



Sketch of Gryphin concept wheel loader based on Volvo CE (2007a)

Methodology: top-down (strategic)

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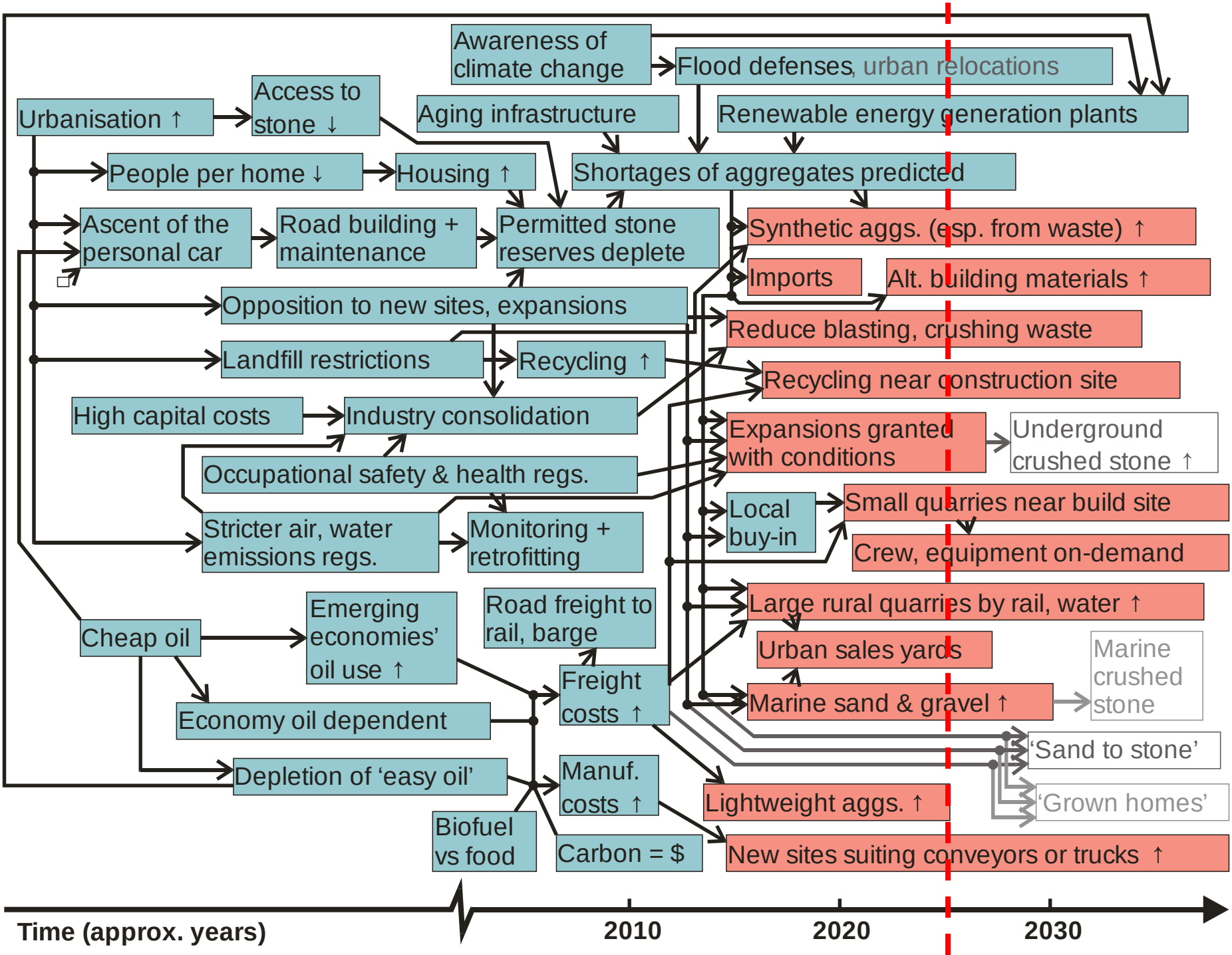
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Lightweight aggs. ↑
'Grown homes'
Biofuel vs food
Carbon = $
New sites suiting conveyors or trucks ↑
Time (approx. years)
2010
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Assessing robustness

Scenario	Suitability
Mid-sized quarries	✓ On-/off-road truck loading
Recycling near building sites	↓ Excavators more common than large loaders
Small quarries with on-demand crews	✓ Could be used for loading both on and off-road trucks
Large rural quarries	↓ Mostly excavators and conveyors; few loaders
Marine sand & gravel	? Mostly dredging, conveying; barge unloading possible
Urban sales yards	✓ Truck loading

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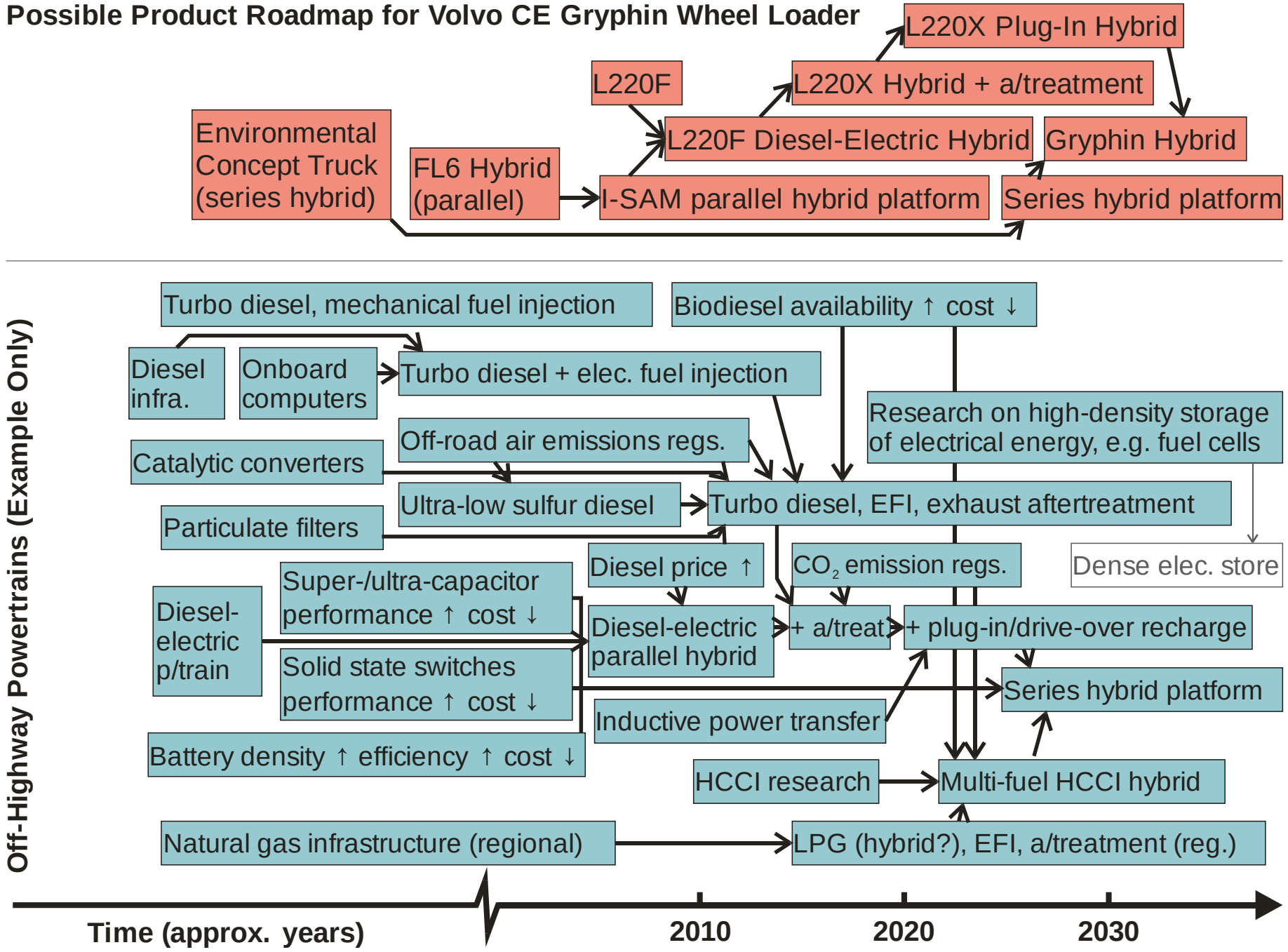
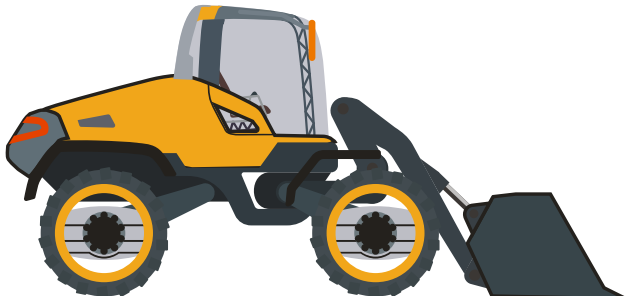
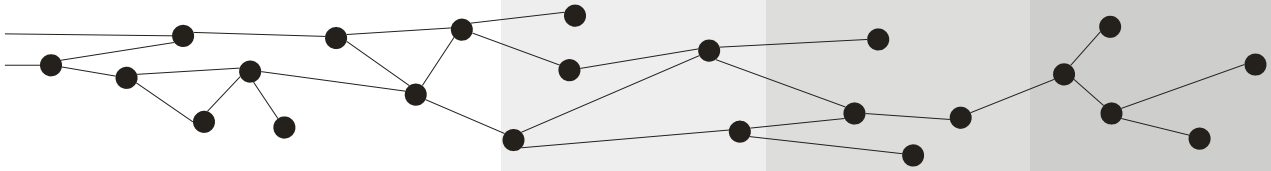

Possible Product Roadmap for Volvo CE Gryphin Wheel Loader
L220X Plug-In Hybrid
L220F
L220X Hybrid + a/treatment
Environmental Concept Truck (series hybrid)
L220F Diesel-Electric Hybrid
Gryphin Hybrid
FL6 Hybrid (parallel)
I-SAM parallel hybrid platform
Series hybrid platform
Off-Highway Powertrains (Example Only)
Turbo diesel, mechanical fuel injection
Biodiesel availability ↑ cost ↓
Diesel infra.
Onboard computers
Turbo diesel + elec. fuel injection
Research on high-density storage of electrical energy, e.g. fuel cells
Off-road air emissions regs.
Catalytic converters
Ultra-low sulfur diesel
Turbo diesel, EFI, exhaust aftertreatment
Particulate filters
Diesel price ↑
CO_2 emission regs.
Dense elec. store
Super-/ultra-capacitor performance ↑ cost ↓
Diesel-electric p/train
Diesel-electric parallel hybrid
+ a/treat
+ plug-in/drive-over recharge
Solid state switches performance ↑ cost ↓
Series hybrid platform
Inductive power transfer
Battery density ↑ efficiency ↑ cost ↓
HCCI research
Multi-fuel HCCI hybrid
Natural gas infrastructure (regional)
LPG (hybrid?), EFI, a/treatment (reg.)
Time (approx. years)
2010
2020
2030

Setting targets (authors' estimates in grey)

Model	Prod. Year	Fuel use
	2007	Baseline
	2012	-10%
	2025	-30%

STRATEGIC

Scenario network map(s) for current and possible future markets



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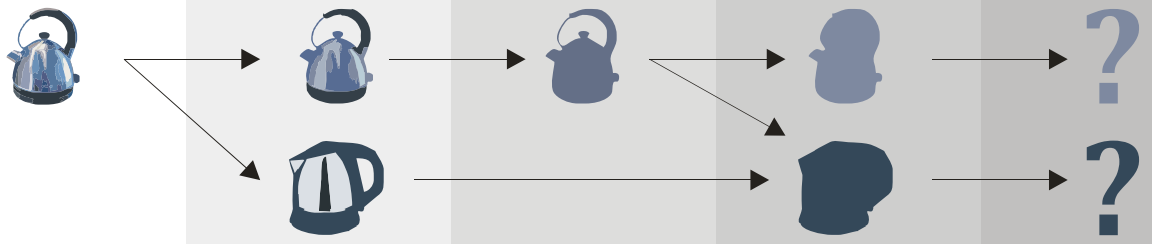

Specification (incl. stricter social-ecological performance criteria)

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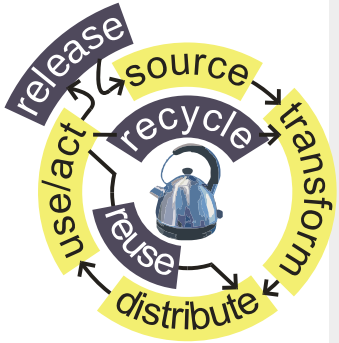

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Time Today 20 years

Thank you! Any questions?

To contact me:

jvic007@aucklanduni.ac.nz