Decarbonising Freight Transport: a review of the technical, operational and managerial options

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Webinar Series | Chair in Energy Sector Management
HEC Montréal,
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THE KLU
KÜHNE LOGISTICS UNIVERSITY

Chair in Energy Sector Management
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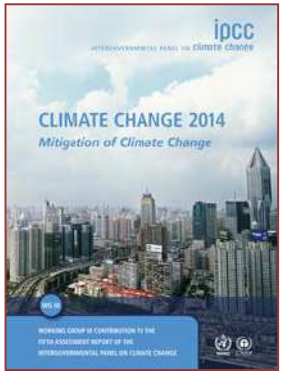
About Kühne Logistics University

- Private, state-accredited university in Hamburg, Germany
- Founded in 2010 by the Kuehne Foundation
- Specialises in logistics and supply chain management
- Sustainability of logistics is a major research focus
- www.the-klu.org

KLU wins German government Higher Education prize for freight transport and logistics 2017

Freight Transport Contribution to Greenhouse Gas Emissions



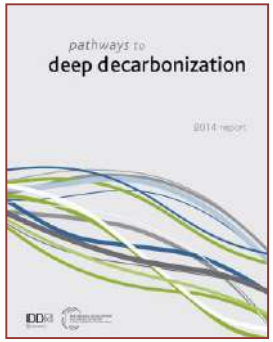
Transport:

2010: **6.5** bn tonnes of CO_{2e}

2050: **12** bn tonnes of CO_{2e} business-as-usual trend

2050: Limit CO_{2e} from all activity to 20bn tonnes

2050: 14% transport share of 20 bn = **2.8** bn tonnes



IDDRI / SDSN (2014)
Freight share of total GHG emissions:

2010: 7%

2050: 16% (business as usual projection)

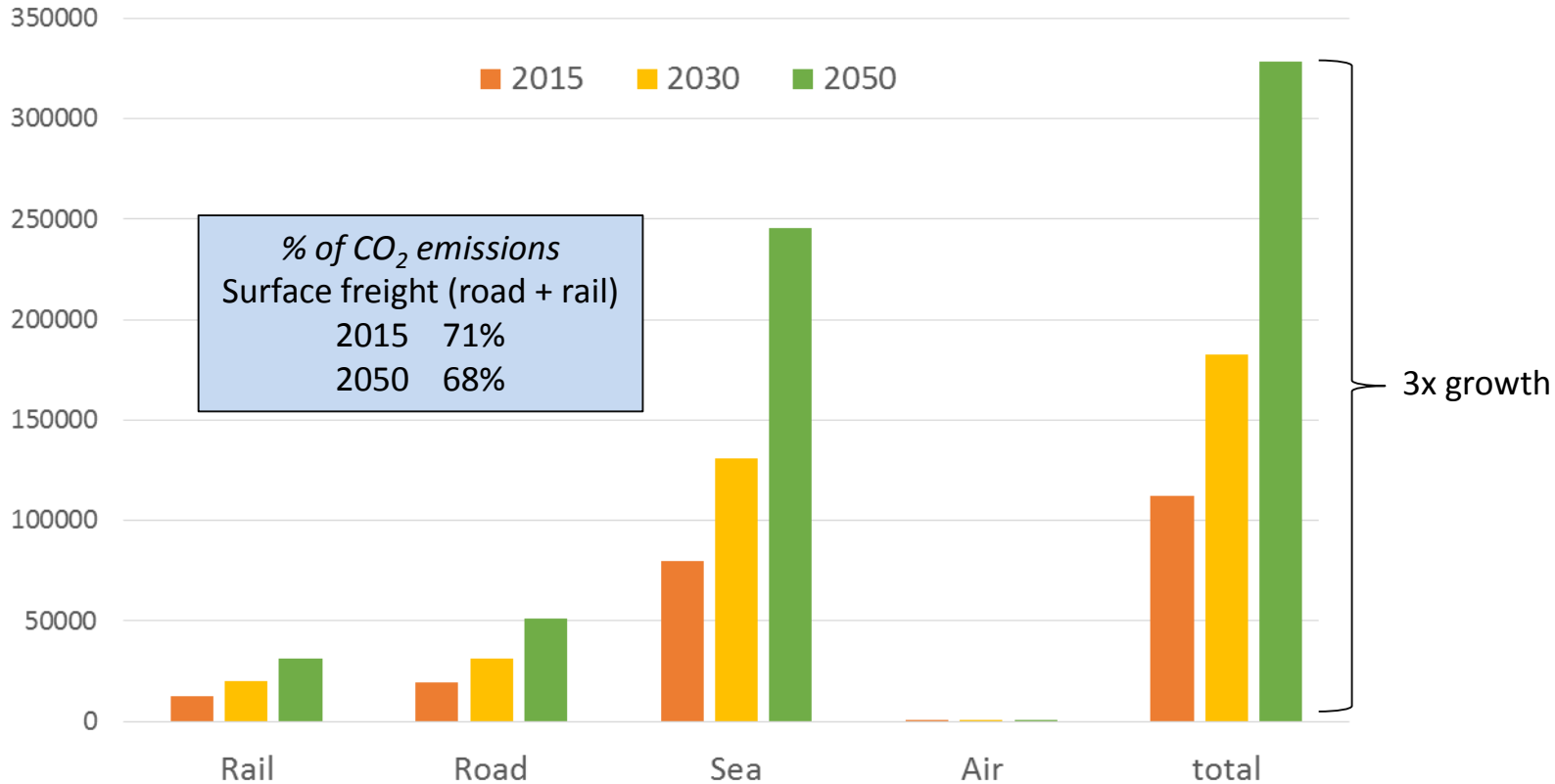
One of the '*most challenging sectors*' in which to achieve '*deep emission reductions*'

To meet EU target of 60% reduction in total CO_2 emissions from freight transport between 1990 and 2050 current carbon intensity of freight transport must fall 80-85%

'*factor 6 reduction*' (Smokers et al, 2017)

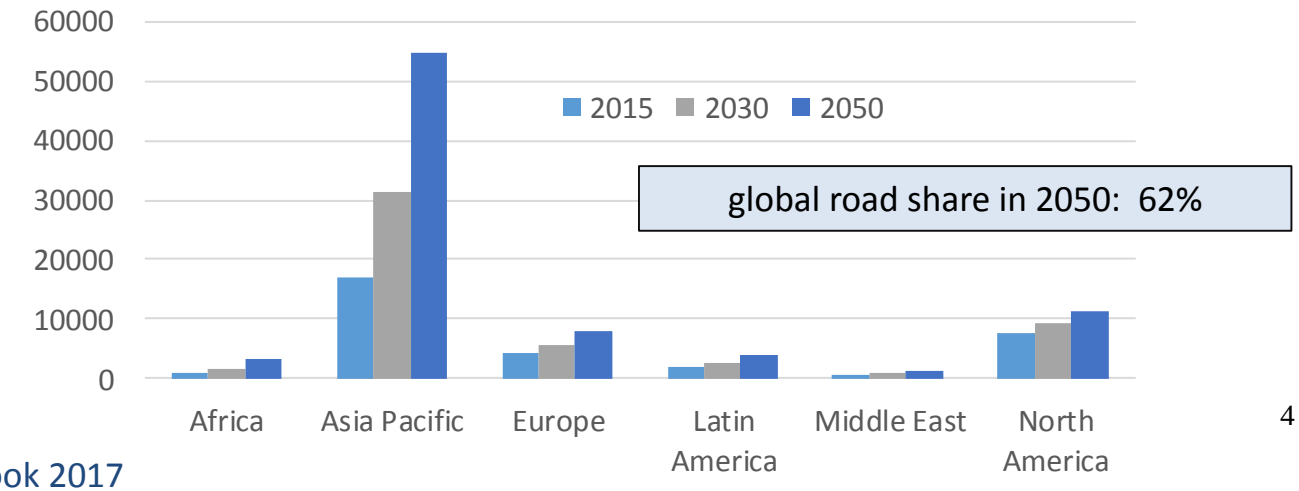
Only 13% of 154 Intended Nationally Determined Contributions (INDCs) submitted to COP21 mention freight transport (*source: Sudhir Gota*)

Global Projection of Freight Traffic Growth: *bn tonne-kms by all modes*



Forecast Growth of Surface Freight (road +rail)

bn tonne-kms



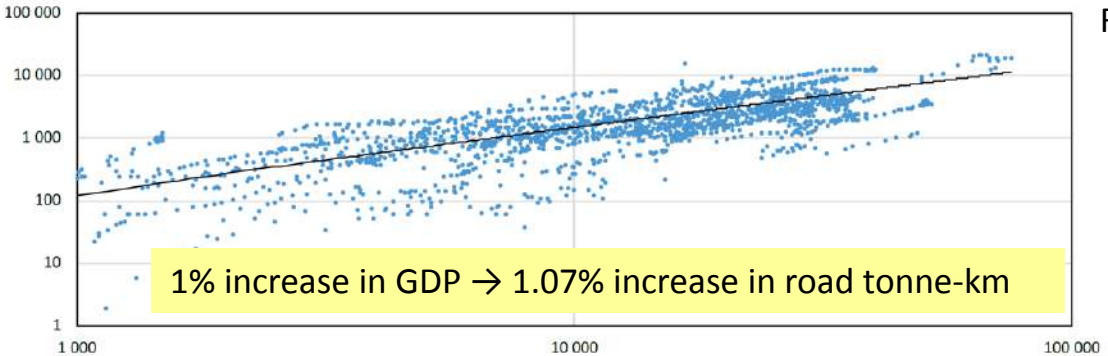
Source: OECD / ITF Transport Outlook 2017

Global Freight Traffic Growth, GDP and CO_2 Emissions

Close correlation between GDP and road freight growth

tonne-km per capita (log scale)

Source: IEA (2017)

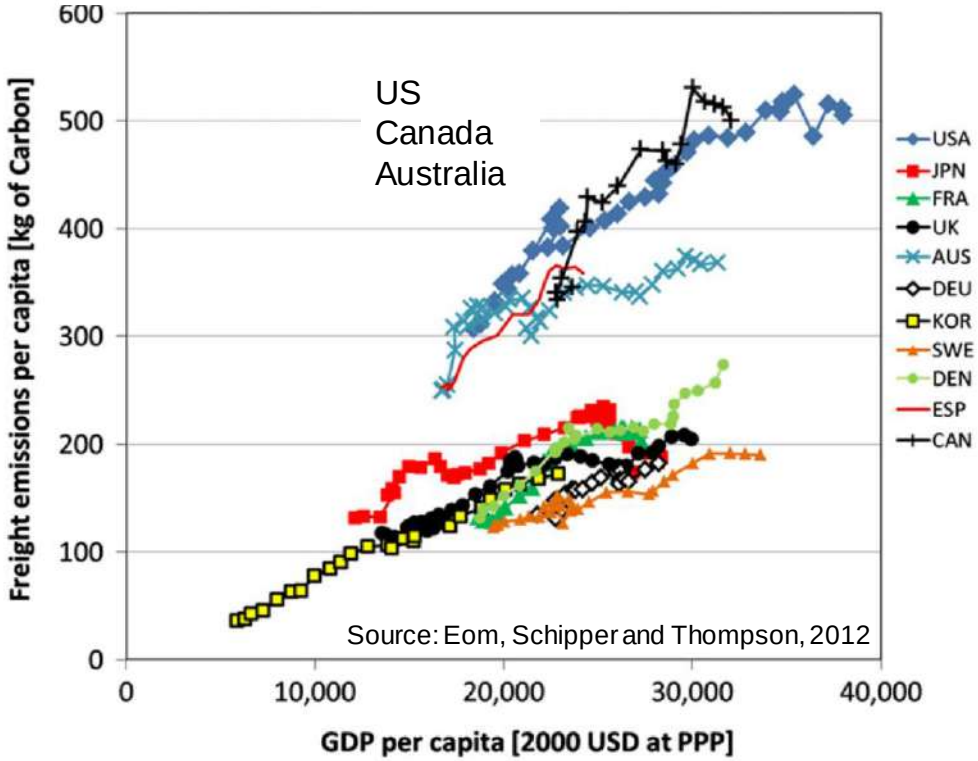


GDP per capita (log scale)

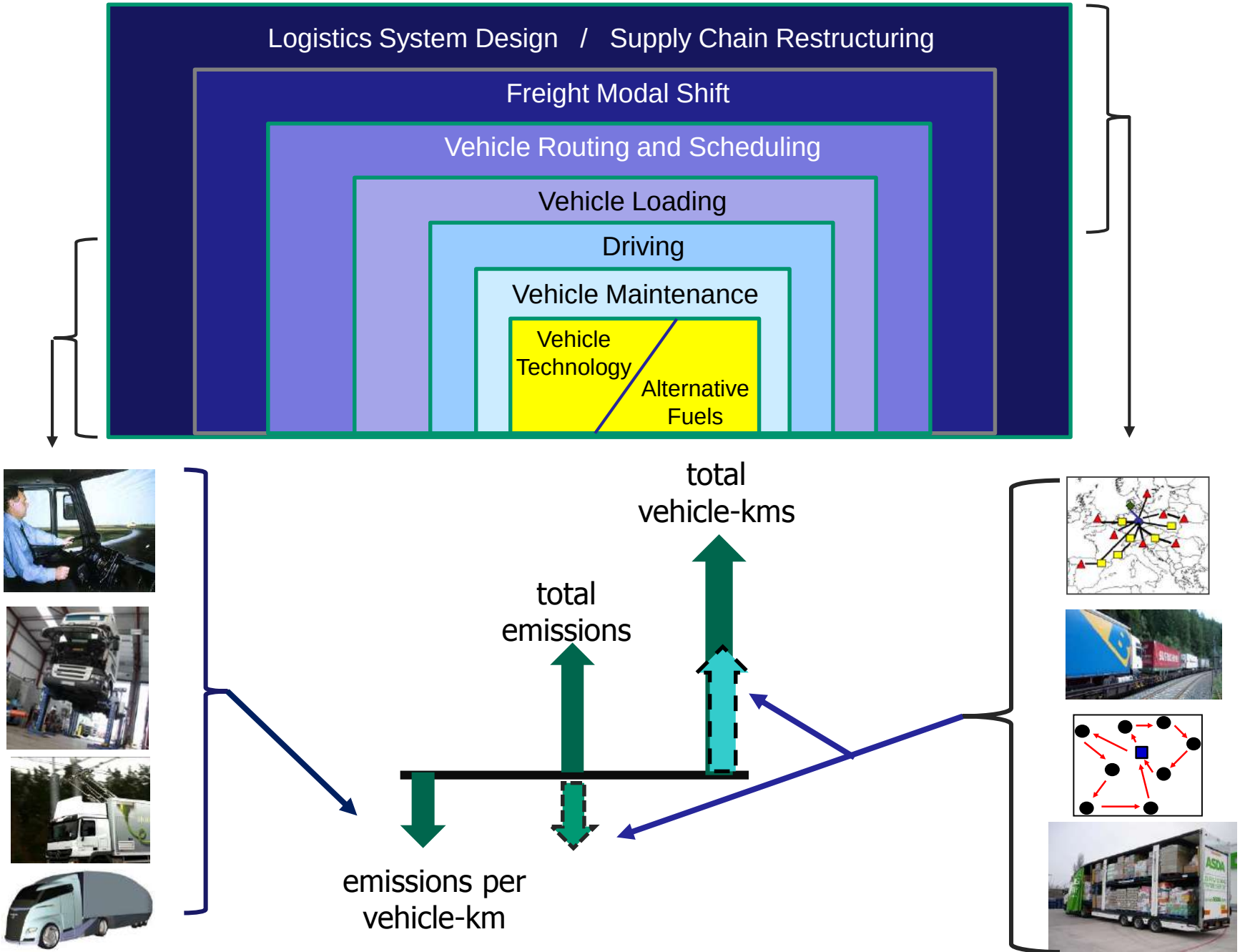
Relationship between road tonne-kms per capita and GDP per capita

Data points for large sample of countries between 1971 and 2014

Freight-related CO_2 emissions/cap and GDP/cap



Scoping the Decarbonisation of Freight Transport



Adapting the Kaya Indentity to Freight Transport

Kaya Identity (IPCC 1990)

Total CO_2 Emissions = Population x GDP/ Population x Energy/GDP x CO_2 / Energy

Freight application of the Kaya Identity

Freight CO_2 Emissions = GDP x tonne-km / GDP x vehicle–km / tonne-km x energy / vehicle-km x CO2 / energy

road

transport intensity | asset utilisation | energy efficiency | carbon content

Freight CO_2 Emissions = GDP x tonne-km / GDP x vehicle –km / tonne-km x energy / vehicle-km x CO2 / energy

rail

transport intensity | asset utilisation | energy efficiency | carbon content

Freight CO_2 Emissions = GDP x tonne-km / GDP x vehicle –km / tonne-km x energy / vehicle-km x CO2 / energy

waterborne

transport intensity | asset utilisation | energy efficiency | carbon content

Freight CO_2 Emissions = GDP x tonne-km / GDP x vehicle –km / tonne-km x energy / vehicle-km x CO2 / energy

aviation

transport intensity | asset utilisation | energy efficiency | carbon content

Kaya Identity (IPCC)

Total CO_2 Emissions = Population x GDP/Population x Energy/GDP x CO_2 / Energy

Freight application of the Kaya Identity

modal split

Freight CO_2 Emissions = GDP x tonne-km / GDP x vehicle –km / tonne-km x energy / vehicle-km x CO2 / energy

road — transport intensity — asset utilisation — energy efficiency — carbon content

Freight CO_2 Emissions = GDP x tonne-km / GDP x vehicle –km / tonne-km x energy / vehicle-km x CO2 / energy

rail — transport intensity — asset utilisation — energy efficiency — carbon content

Freight CO_2 Emissions = GDP x tonne-km / GDP x vehicle –km / tonne-km x energy / vehicle-km x CO2 / energy

waterborne — transport intensity — asset utilisation — energy efficiency — carbon content

Freight CO_2 Emissions = GDP x tonne-km / GDP x vehicle –km / tonne-km x energy / vehicle-km x CO2 / energy

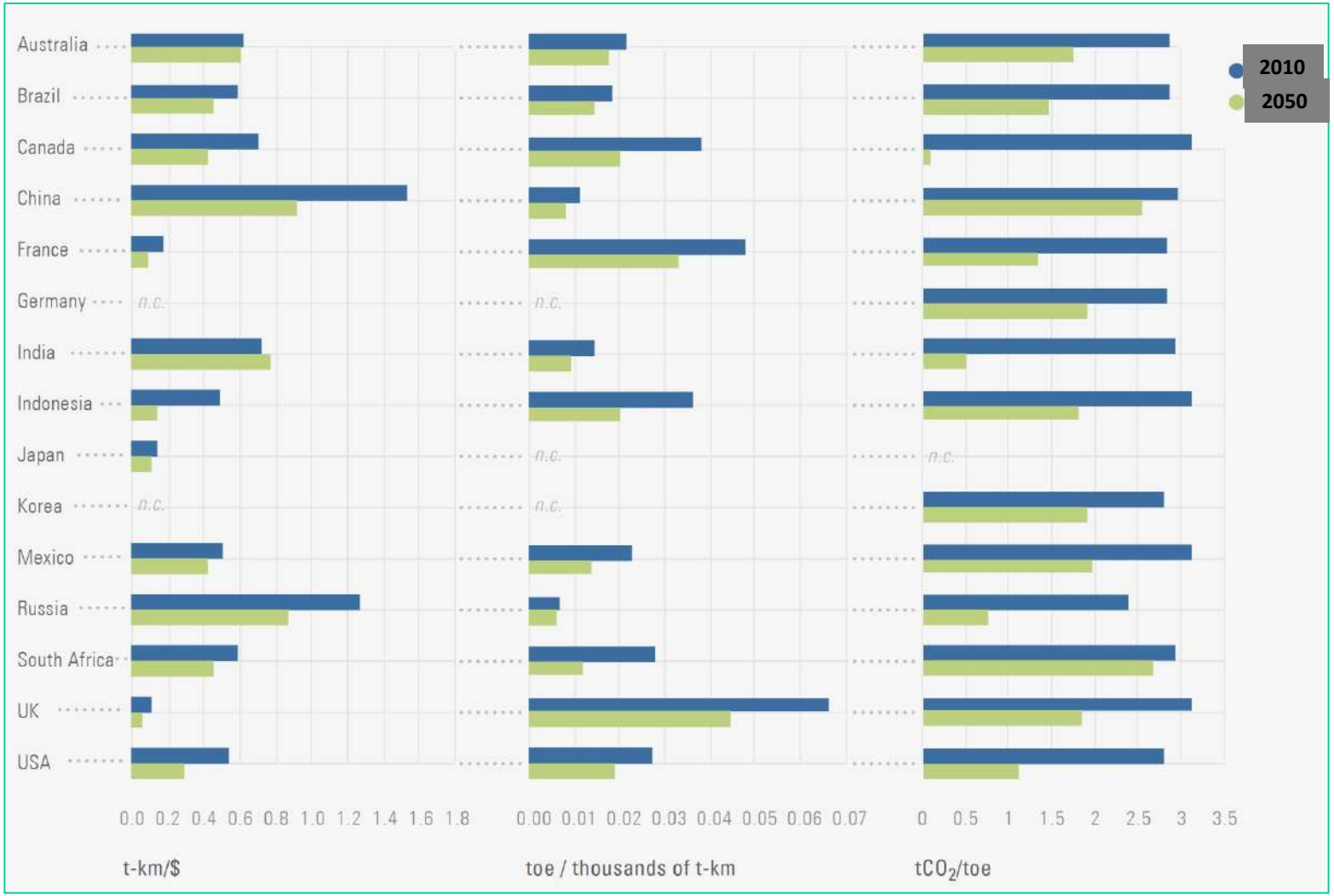
aviation — transport intensity — asset utilisation — energy efficiency — carbon content

→ total freight-related CO_2 emissions

Most countries lack necessary freight data to calibrate the key parameters

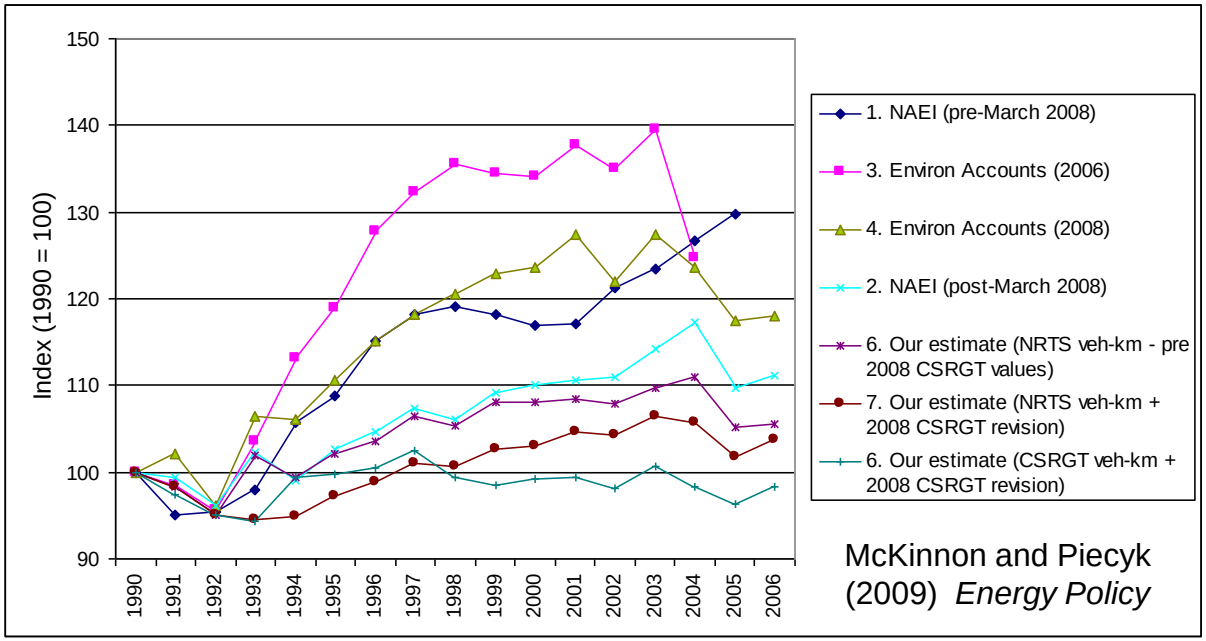
Potential for Decarbonising Freight Transport in 15 Countries: *2010 - 2050*

decoupling of freight tonne-km from GDP	Decoupling energy use from freight t-km	Decoupling freight energy use from related emissions
freight transport intensity	energy intensity of freight transport	carbon intensity of freight energy

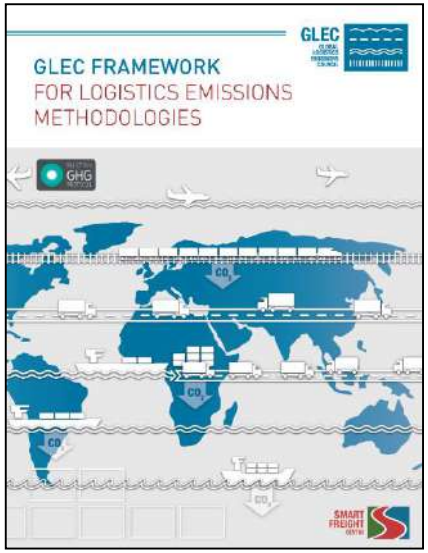


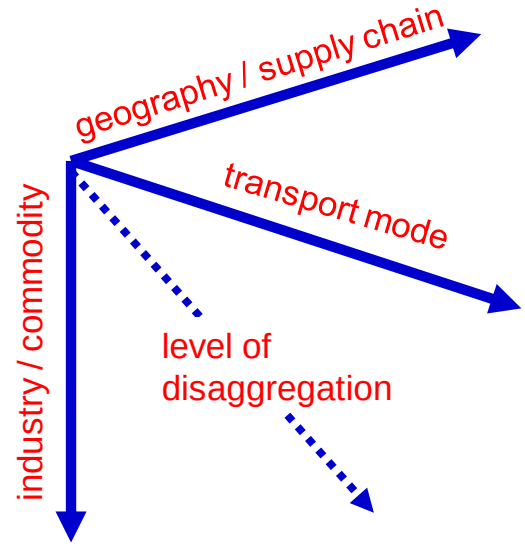
Source: IDDRI / SDSN (2014) 'Pathways to Deep Decarbonisation'

Estimation of CO_2 Emissions from Freight Transport: *an inexact science*



Estimates of CO_2 emissions from UK road haulage 1990-2006





multi-dimensional harmonisation

Targets to Reduce the Carbon Intensity of Freight Transport

company	normaliser	time period	% carbon reduction target
Deutsche Post / DHL	*'every letter and parcel delivered, every tonne of cargo transported and every sq.m. of warehouse space'*	2007-2020	30%
DB-Schenker	Tonne-km	2006-2020	At least 20%
UPS	UPS Transportation Index	2010-2017	5%
UPS Airlines –Global	Pounds of CO_2 emitted for every ton of capacity transported on nautical mile	2005-2020	20%
Fedex (aircraft)	available ton mile (ATM)	2005-2020	20%
TNT (Mail and Express)	not specified	2007-2020	45%
Maersk Line	not specified	2007-2020	25%
NYK	'unit of transportation from vessels'	2006-2013	10%

Source: McKinnon and Piecyk, 2012

40% improvement in carbon intensity of global logistics between 2010 and 2020

Strong growth in the total amount of logistics activity offsets carbon intensity reductions

Inconsistency: *government targets for absolute CO_2 reductions vs corporate CO_2 intensity targets*

Deutsche Post DHL Group commits to zero emissions logistics by 2050

- Ambitious interim goals for carbon efficiency, local emissions, green customer solutions and employee engagement by 2025
- Previous climate protection target achieved ahead of schedule
- Frank Appel: "The decisions we make today will determine how our children live 30 years down the line."

Deutsche Post DHL Group, the world's

Frank Appel: "The decisions we make today will determine how our children live 30 years down the line."

Source: DHL website

SCIENCE BASED TARGETS

DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

Setting corporate GHG reduction targets in line with evidence from climate science

Freight is in the residual 'Other transport' category

Five Sets of Decarbonisation Initiatives for Freight Transport

Reduce Demand for Freight Transport

Shift Freight to Lower Carbon Transport Modes

Optimise Vehicle Loading

Increase Energy Efficiency of Freight Movement

Reduce the Carbon Content of Freight Transport Energy

Future Material Content of the Economy

'De-growth' – reaching '*peak stuff*'? (Steve Howard, IKEA)

– substituting experiences for physical goods?

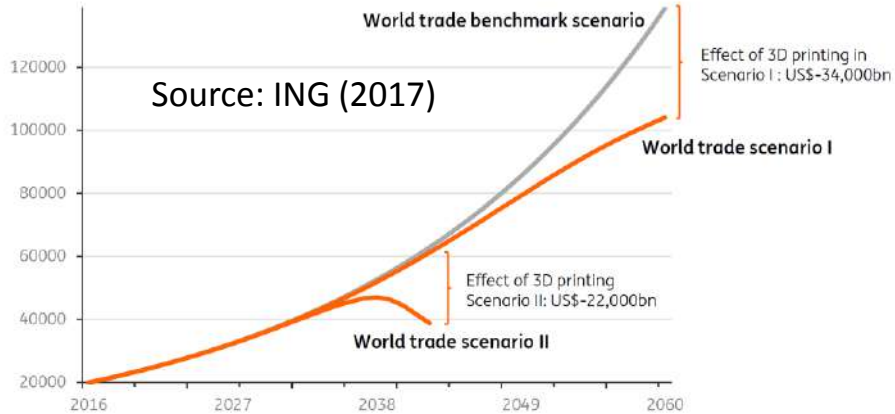
– move to 'sustainable consumption'?

Developed world perspective

Huge future demand for material consumption in lower income countries

Dematerialisation: improve '*material efficiency*':

- Increased recycling and remanufacturing: *circular economy*
- Digitisation of physical products: *freight movement → electronic transmission*
- Designing products with less material: *miniaturisation, lightweighting*
- 3D Printing: *less material, less wastage, eliminates supply chain links*



Source: ING (2017)

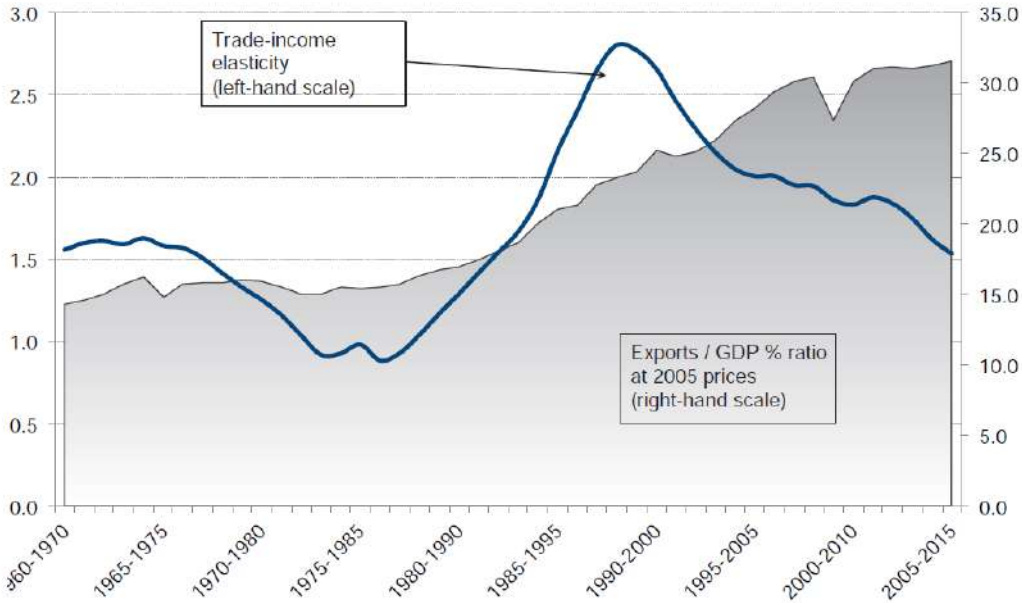
To have large impact on freight emissions:

- Need major uptake of 3D printing at domestic level and local 'fab' shops
- Huge increase in functionality of 3D printers
- Collapse in unit price of 3D printing

Future Trends in International Trade and Globalisation

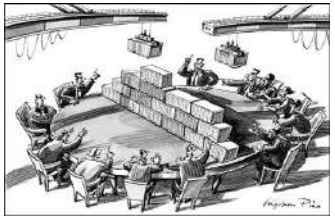
Relationship between trade and global GDP

Declining ratio of trade to GDP



temporary aberration or structural change in the global economy?

New era of protectionism?
Doha Round failed
TPP and TTIP stalled
Brexit / Trump



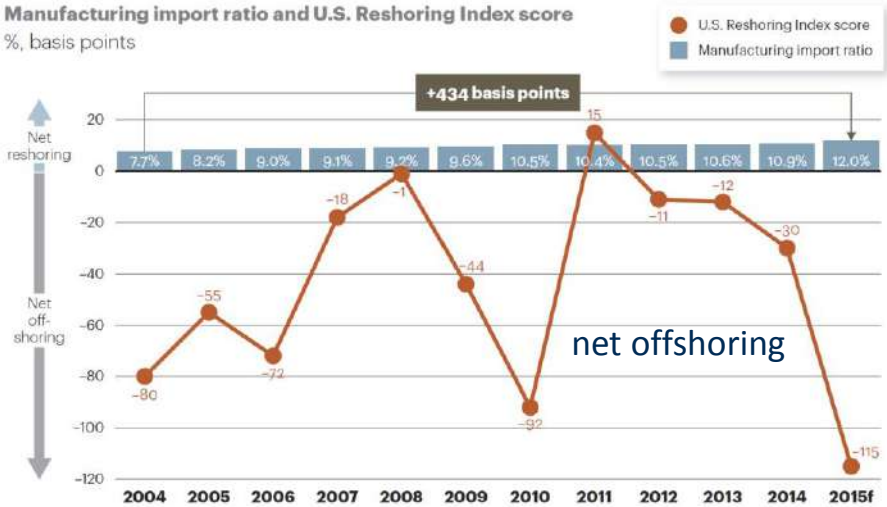
WTO Trade Facilitation Agreement (Bali 2013)

- will reduce total trade costs by 13-15%
- generate additional $1 trillion in trade

Reshoring debate

Boston Consulting Group (2015)

A T Kearney (2015)



EPRS European Parliamentary Research Service

Briefing 21/03/2014

Reshoring of EU manufacturing

Reduce the Growth in Demand for Freight Transport

Restructuring of supply chains


- relocalize production / sourcing
- decentralize inventory
- reversal of key business trends
- high carbon-mitigation costs

Overall CO_2 impact of relocalization

Transport = typically a small % of life cycle emissions

Source products where production-related emissions are minimised

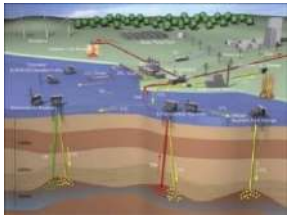
Roughly 40% of international trade yields net CO_2 emission reductions (Cristea et al 2013)

Fossil fuel phase-out


- 4.1 billion tonnes of coal, oil and gas were moved internationally by sea in 2015 - 41% of all maritime trade by weight
- Constructing renewable energy infrastructure is material- and transport-intensive


New freight growth sectors

carbon capture and storage



air conditioning

adaptation of infrastructure to climate change


resettlement of populations

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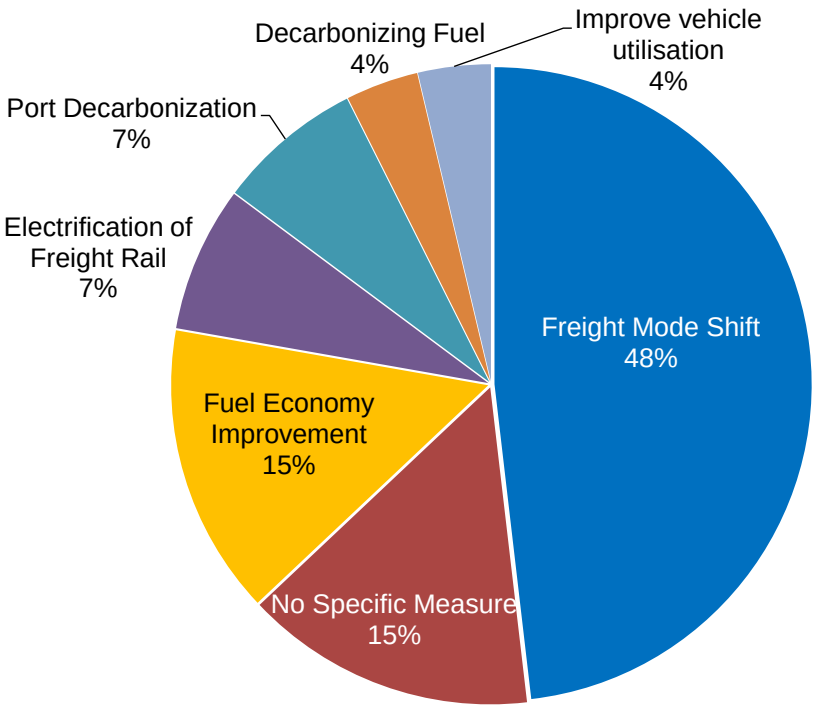
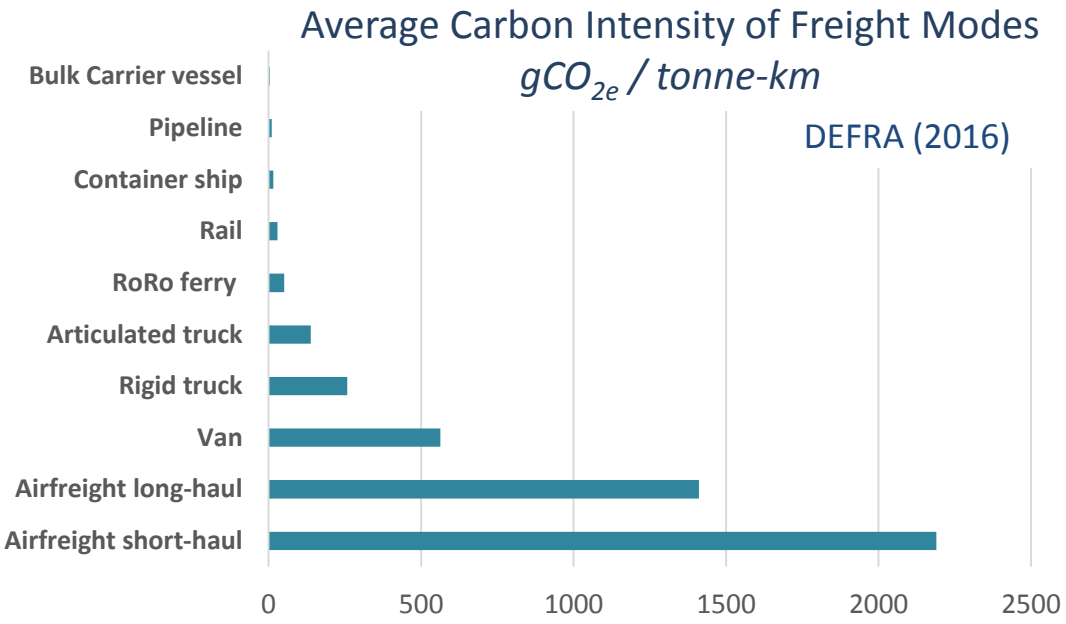
Shifting Freight to Lower Carbon Transport Modes

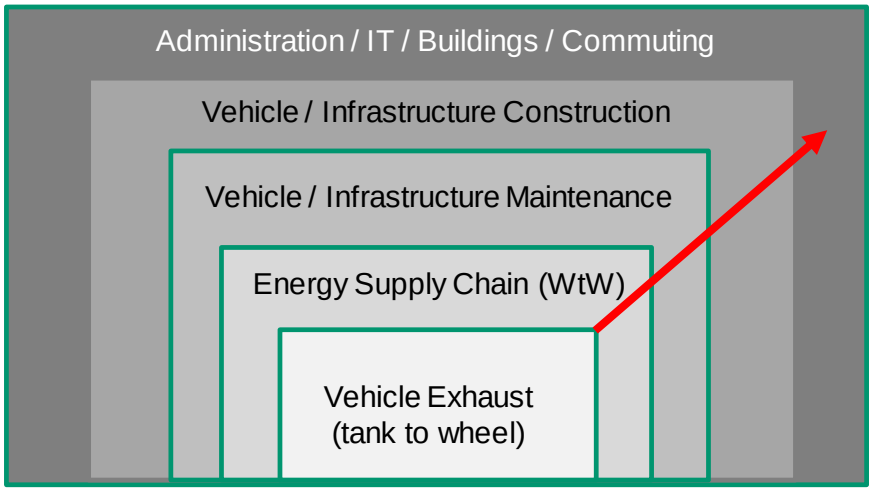


Freight decarbonisation measures in INDCs submitted to COP21

Source: Sudhir Gota (2015)



Need holistic measurement of freight-related emissions



Adapted from NTM

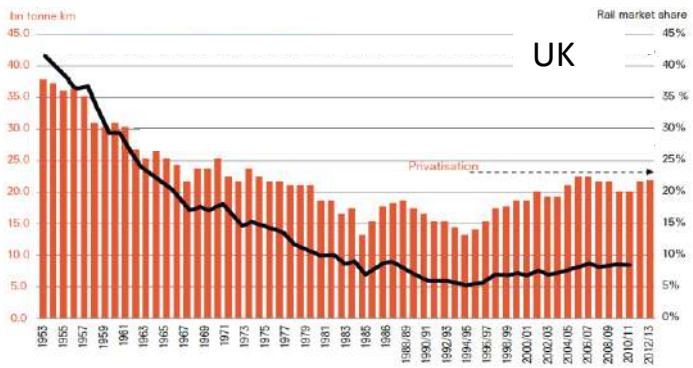
Carbon intensity of intermodal services?

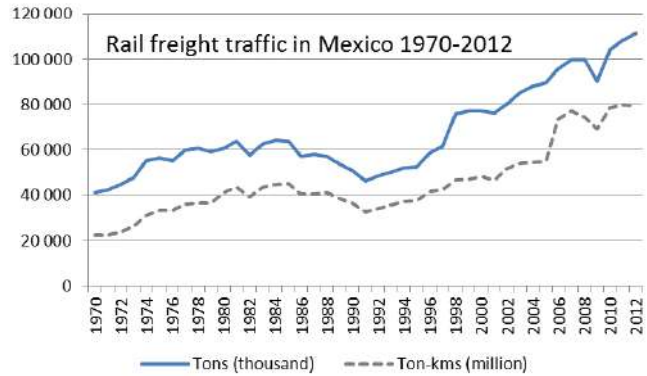
Need to express modal carbon intensities on a door-to-door basis

Need to base policy and mode choice decisions on projection of **future** modal carbon intensities

Shifting Freight to Lower Carbon Modes

Long term shift to trucking: EU28 - *road increased share of tonne-kms from 67% (1995) to 72% (2014)*
US - *road increased share of tonne-kms from 41% (1995) to 48% (2013)*
India - *rail share of tonne-kms halved between 1990 (63%) and 2015 (31%)*

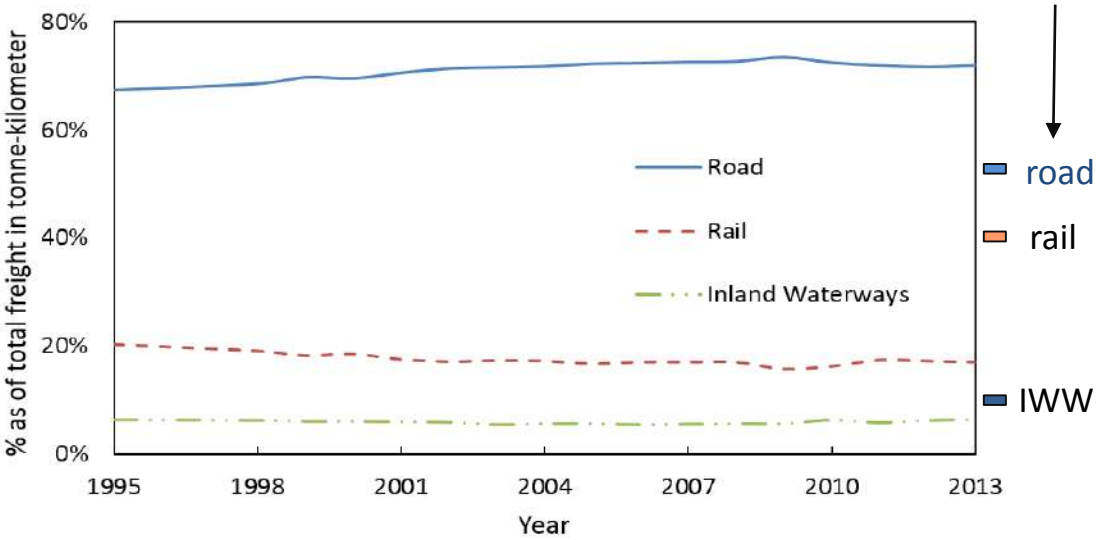




Mexico

2030 modal shares if EU 2011 White Paper target is achieved*

EU freight modal split

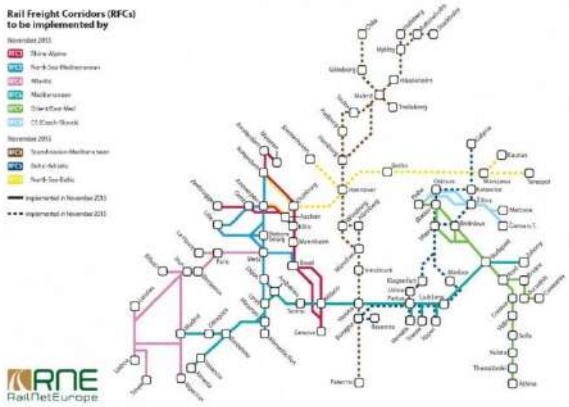


- difficult to reverse of past modal trends
- past government efforts merely eased the decline of lower carbon modes
- '*logistical lock-in*' – alignment of industrial property to road network
- managerial reluctance to risk shifting mode

*based on analysis by Tavasszy and van Meijeren (2011)

Promoting the Use of Low Carbon Freight Transport Modes

concentrate modal shift efforts on strategic intermodal corridors



support development of intermodal hubs

apply synchromodality principle

	Location	Cost	Travel time	Distance	Transportmode
1	Karlsruhe Industriegebiet	0.00	10:16	0.0	TM_ROAD
2	Wörth am Rhein Hafen	63.00	10:58	29.5	LOAD_ROAD_RAIL
3	Wörth am Rhein Hafen	63.00	2 16:00	29.5	TM_TTN_RAIL
4	Hamburg CTB Burchardkai	301.00	3 14:15	722.5	LOAD_RAIL_SHORTSEA
5	Hamburg CTB Burchardkai	301.00	7 17:00	722.5	TM_TTN_SHORTSEA
6	Moss Container Terminal	400.00	10 09:00	1,564.5	LOAD_SHORTSEA_ROAD
7	Moss Container Terminal	400.00	10 09:30	1,564.5	TM_ROAD

Investigating synchromodality from a supply chain perspective

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[d] Supply Network Innovation Center, Strombeek-bever 1853, Belgium

internalise the external costs of freight transport

subsidise use of alternative modes which cut CO_2

use land use planning policies to favour modes

prioritise investment in rail and water infrastructure

alter regulatory / competitive frameworks

provide advisory services on modal shift

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Empty Running of Freight Vehicles

Data only for trucking

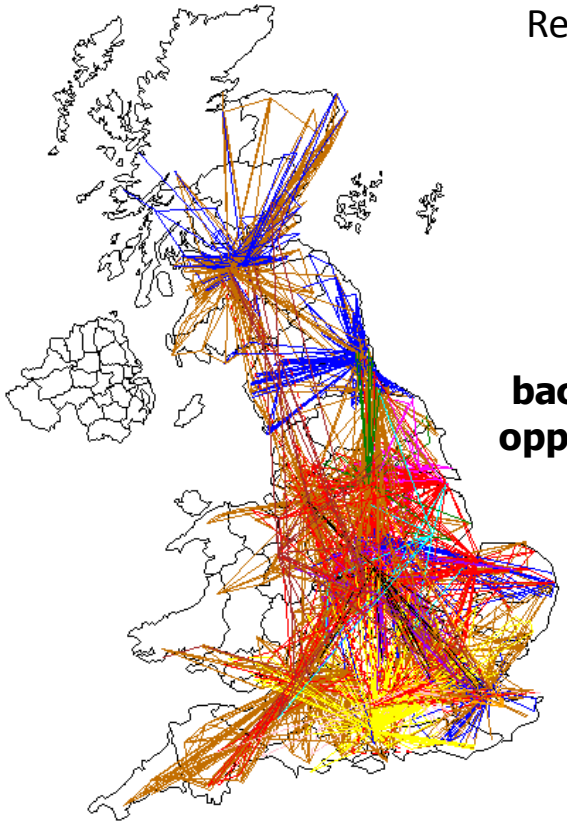
EU28: % of truck-kms run empty (2014)

Within countries:	25%
International:	13%
All trucking:	21%

US SmartWay fleets:	16.7% (2014)
Australia:	29% (2012)
India:	estimates of 40-50%

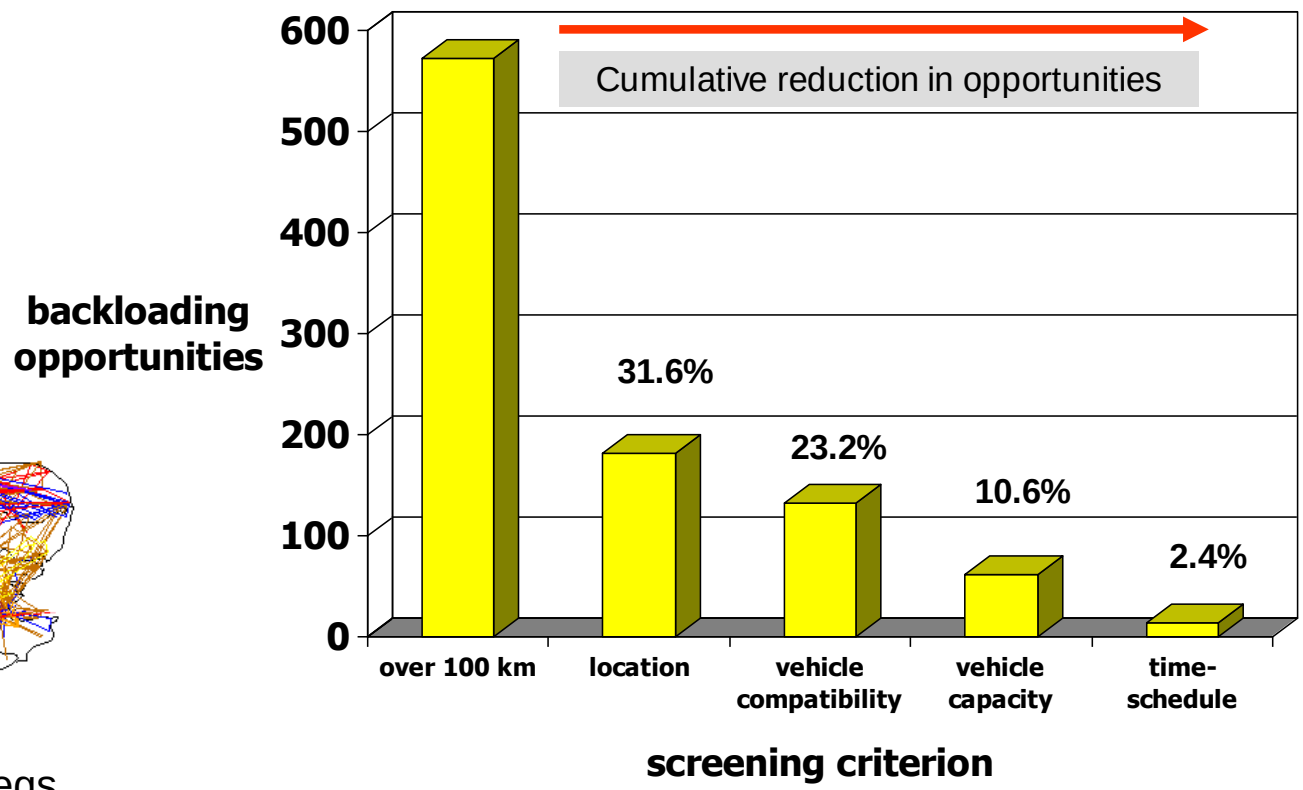
Main reasons for empty running:

- geographical imbalances in traffic flow: *triangulation*
- lack of knowledge of available loads: *online freight exchanges*
- incompatibility of vehicles and loads
- tight scheduling of deliveries
- journeys too short to justify backloading
- lack of co-ordination between transport and purchasing depts



29 fleets: 8995 journey legs

Retrospective assessment of the potential for backloading



Source: McKinnon and Ge (2005)

Optimise Vehicle Loading

loaded trips

weight-based measures

freight density

space-related measures

2-dimensional view

deck-area coverage

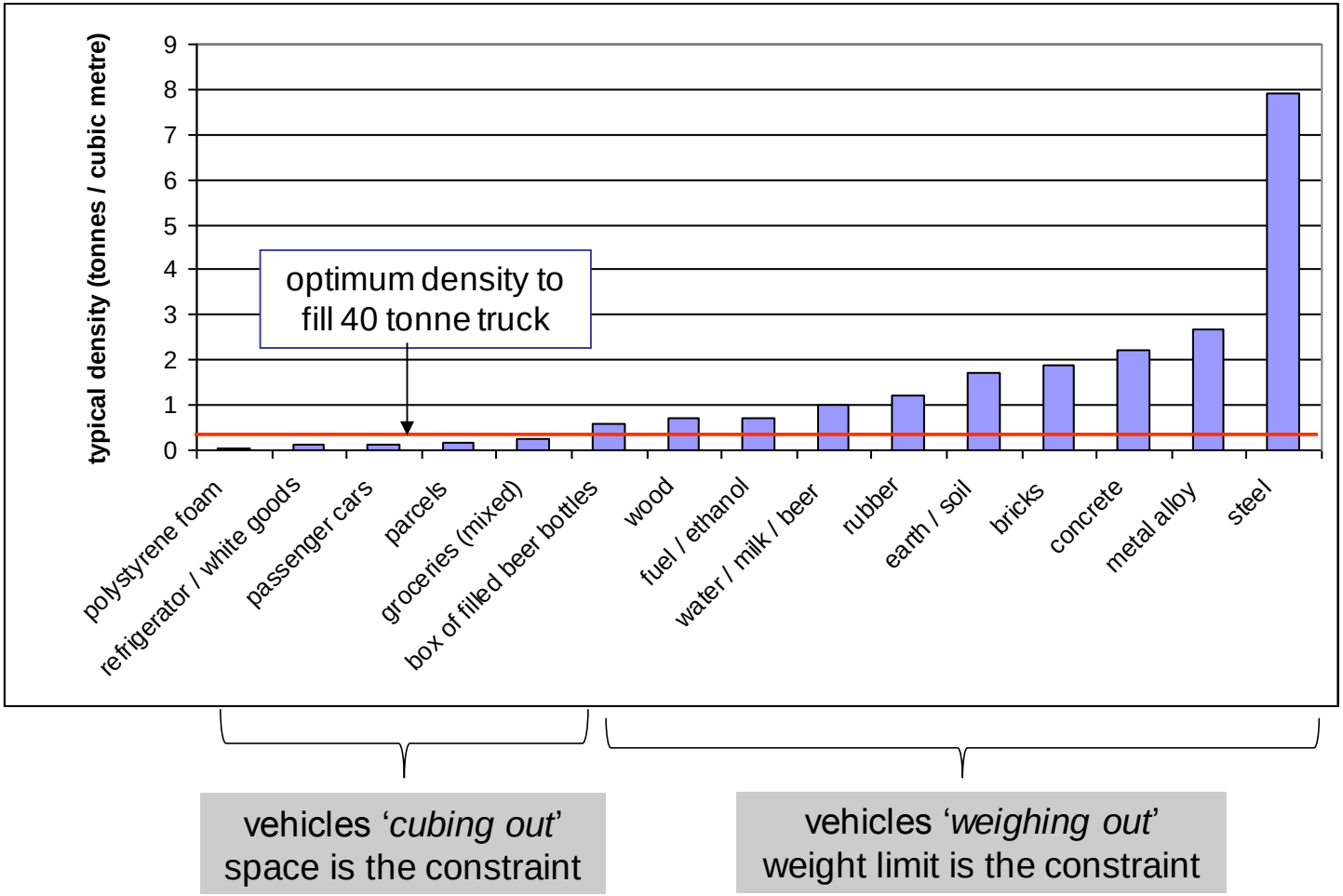
'load length"

stacking height

3-dimensional view

cube utilisation

Density of Freight and Vehicle Carrying Capacity



- very difficult to assess the potential for increasing vehicle utilization and cutting CO_2 by this means
- under-utilization of vehicle capacity is usually not due to inefficiency / poor management
- logistics optimization often involves trading off vehicle utilization for less inventory, higher sales etc

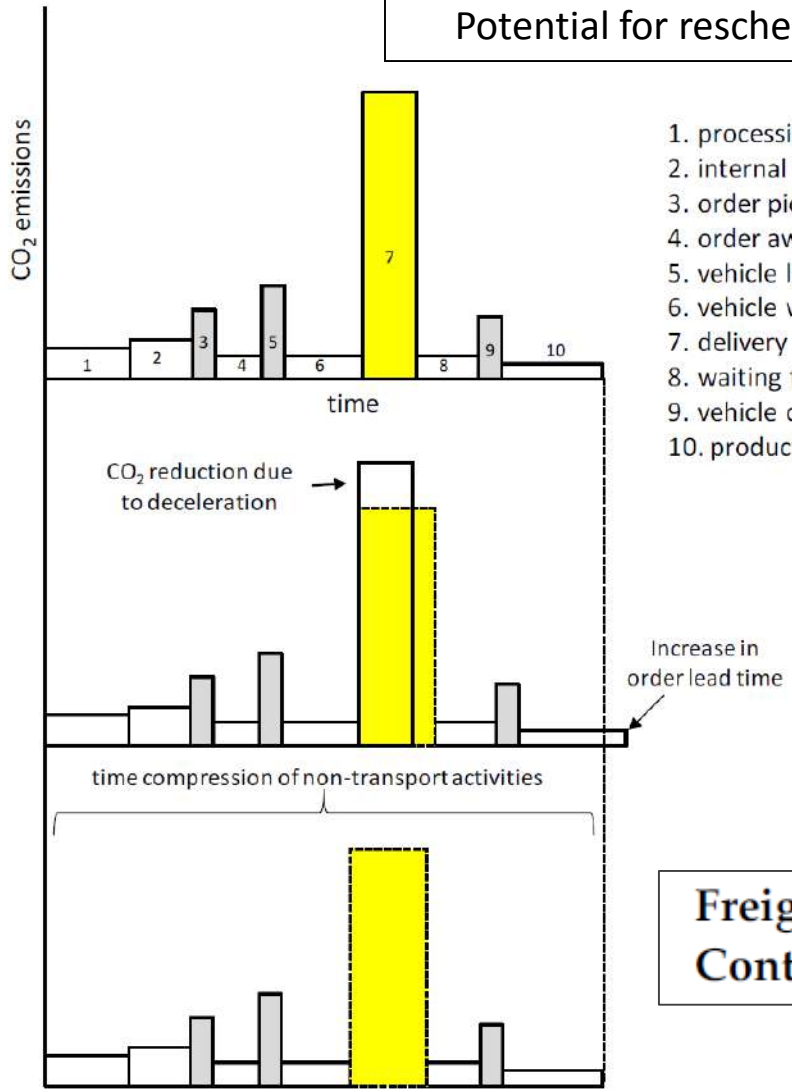
Time to relax the Just-in-Time principle?

Just-in-Time Replenishment

Relaxing JIT:
- more time to consolidate loads and find backhauls
- easier for rail and water to compete for freight

But:
- JIT is business paradigm that minimizes waste
- contributes to energy and CO_2 savings elsewhere

Potential for rescheduling supply chain processes to cut CO_2 emissions?



1. processing of inbound order
2. internal administration / checks
3. order picking
4. order awaiting loading
5. vehicle loading
6. vehicle waiting time
7. delivery
8. waiting time at reception point
9. vehicle off-loading and put-away
10. product storage prior to use / sale

- accelerate internal processes
- Internal time savings offset longer transit times
- net CO_2 saving within fixed order lead time

Freight Transport Deceleration: Its Possible Contribution to the Decarbonisation of Logistics

McKinnon (2016) *Transport Reviews*

Supply Chain Collaboration

examples

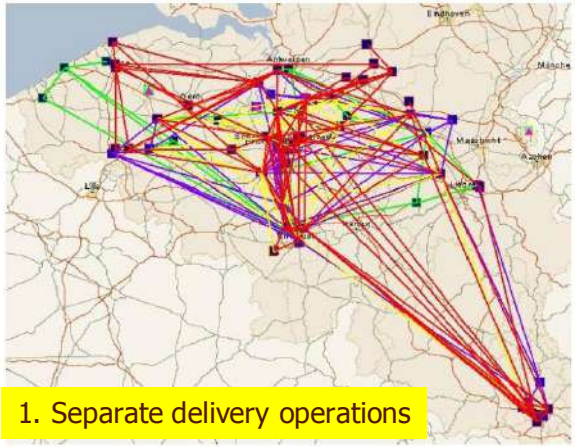
P&G and Tupperware (EU)

Nestle-United Biscuits (UK)

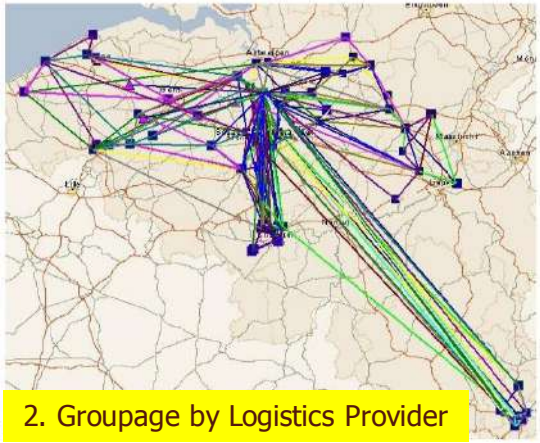
Deep decarbonisation of freight transport will require much greater sharing of logistics assets

- change in the corporate mindset
- exhaustion of internal efficiency improvements
- confirmation of legality
- new IT tools support collaborative working

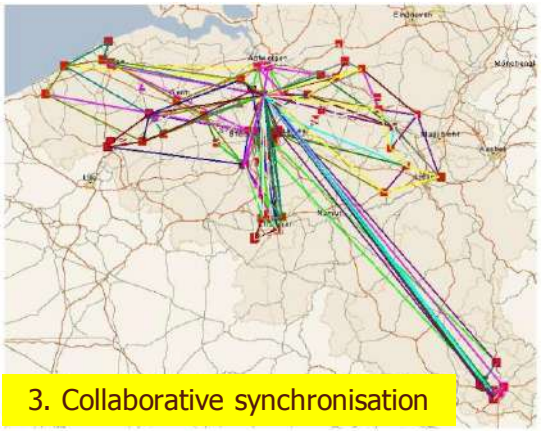
Nestle – Pepsico Horizontal Collaboration in Benelux



1. Separate delivery operations



2. Groupage by Logistics Provider



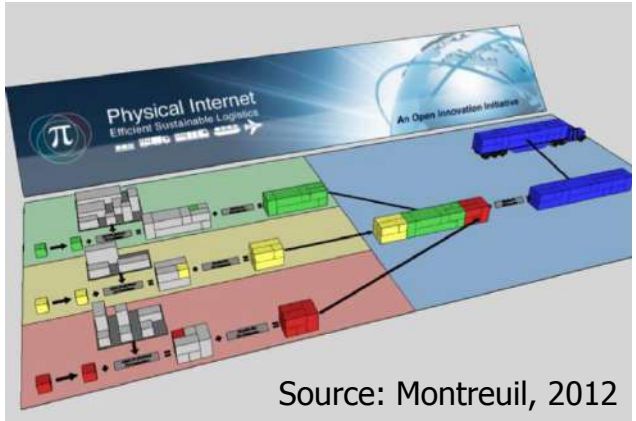
3. Collaborative synchronisation

	Kg CO2 / tonne
1. Separate delivery	43.8
2. Groupage	27.3
3. Collaborative synchronisation	20.3

EU project: CO3

Source: Jacobs et al 2014

The Physical Internet



Source: Montreuil, 2012

applying the networking of principles of the internet to the physical movement of freight
Open, collaborative network with full visibility and incentivized asset sharing
'*Physical encapulation*' of goods in a new generation of modularised containers'

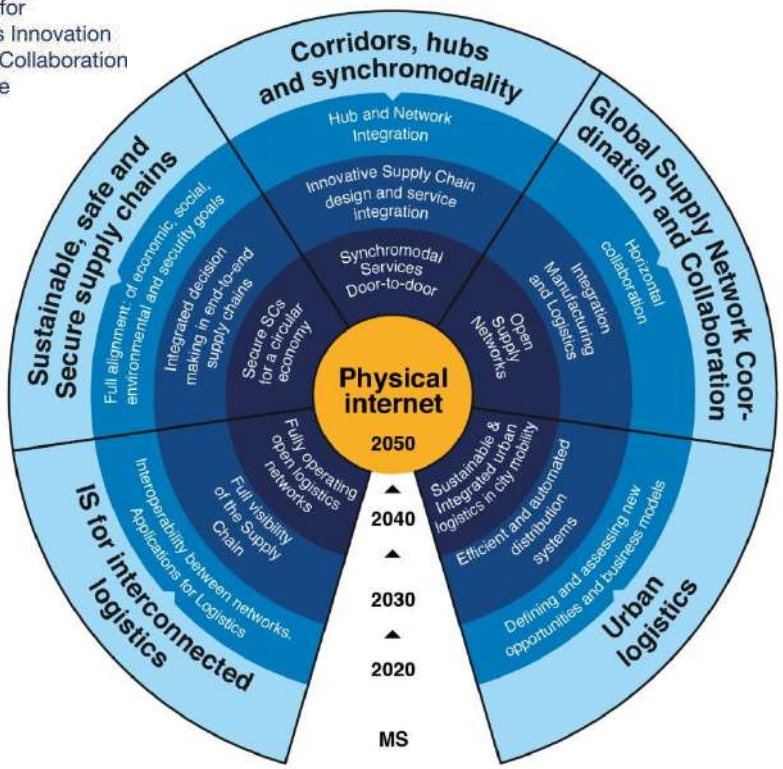
Physical Internet
Efficient Sustainable Logistics

alice | Alliance for Logistics Innovation through Collaboration in Europe

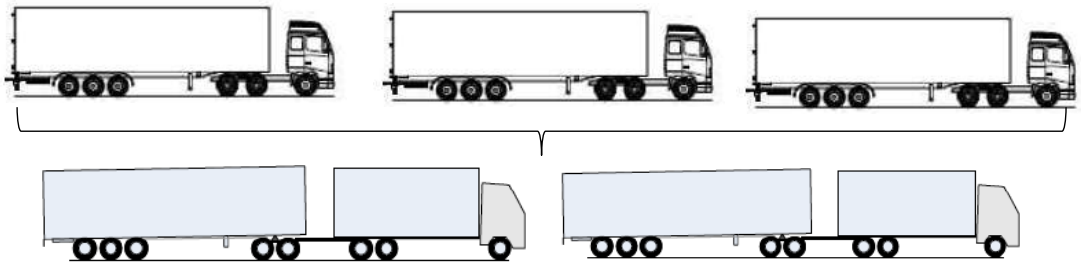
Vision for the future of logistics

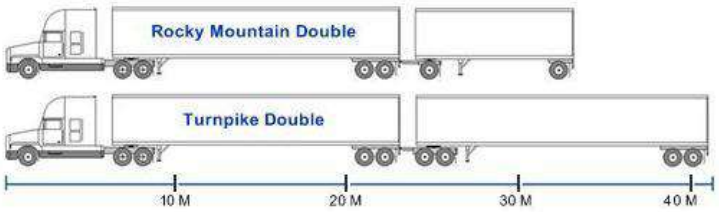
Potentially large efficiency gains and CO_2 savings

Is it likely to be realized in time to meet carbon reduction targets?

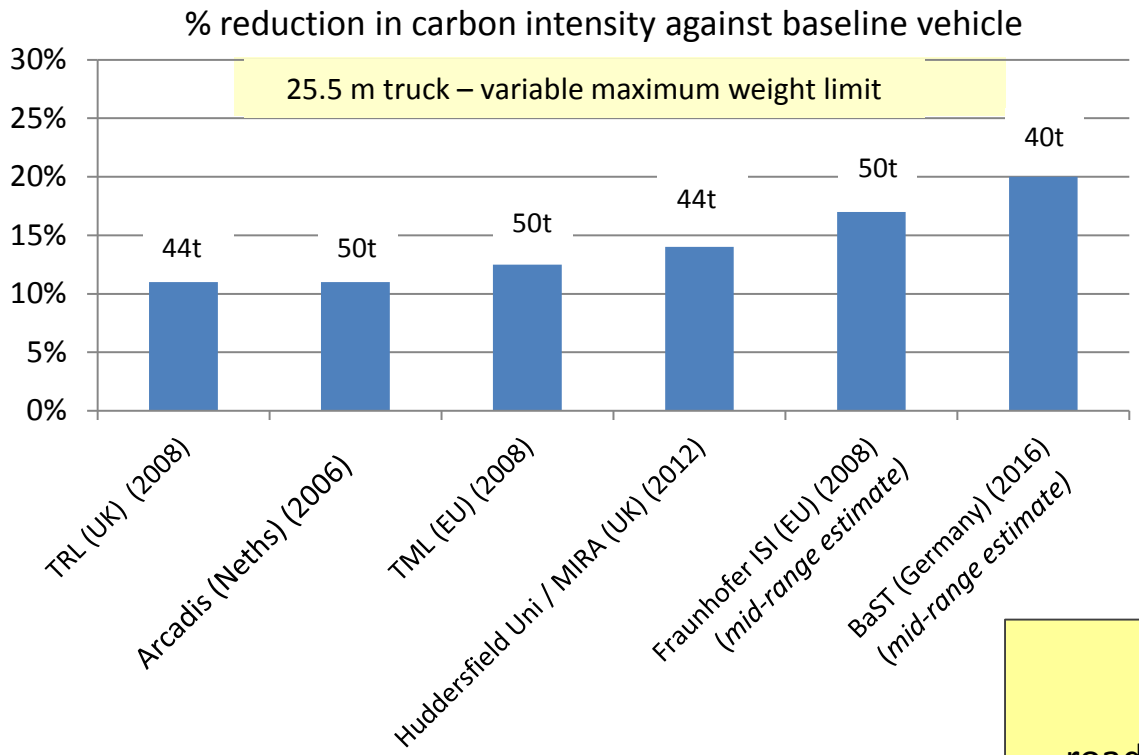


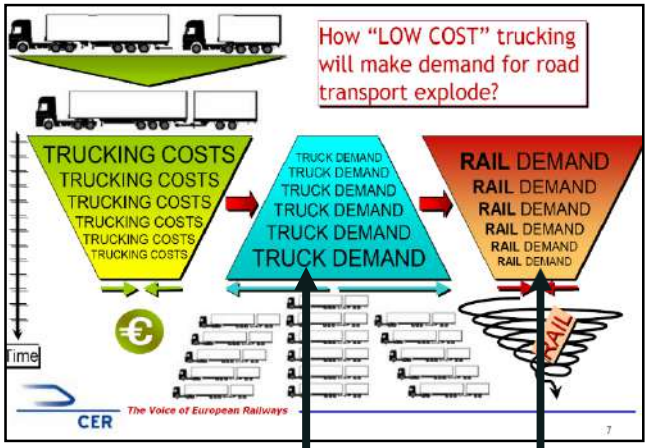
Raise Truck Size and Weight Limits – *within infrastructural constraints*





2 truck for 3 substitution: load consolidation → reduced energy use and emissions per tonne-km





assumed modal and cross-modal price elasticities?

freight modal shift
versus
road freight efficiency improvement

Conflict between freight decarbonisation strategies

Five Sets of Decarbonisation Initiatives for Freight Transport

Reduce Demand for Freight Transport

Shift Freight to Lower Carbon Transport Modes

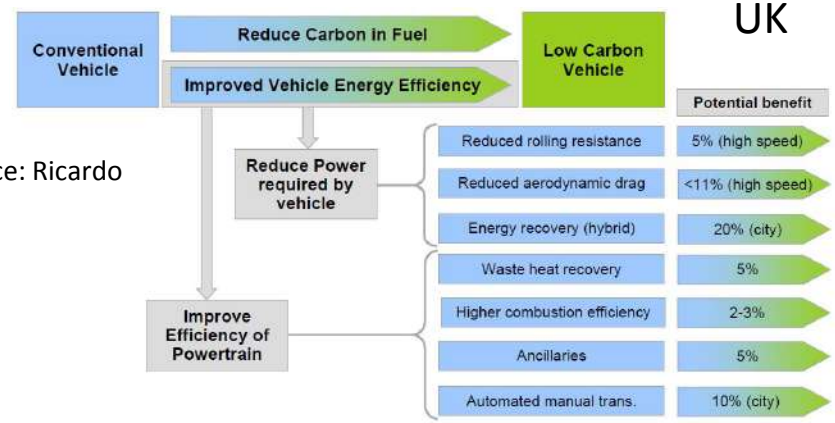
Optimise Vehicle Loading

Increase Energy Efficiency of Freight Movement

Reduce the Carbon Content of Freight Transport Energy

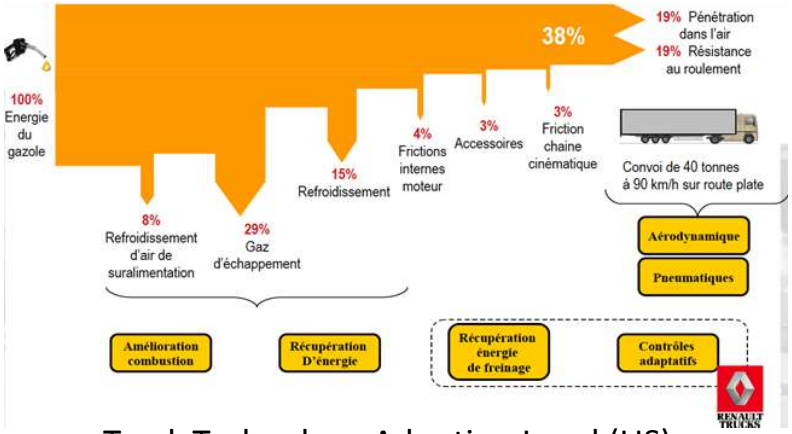
Improving the Energy Efficiency of Freight Transport: *Truck Technology*

UK

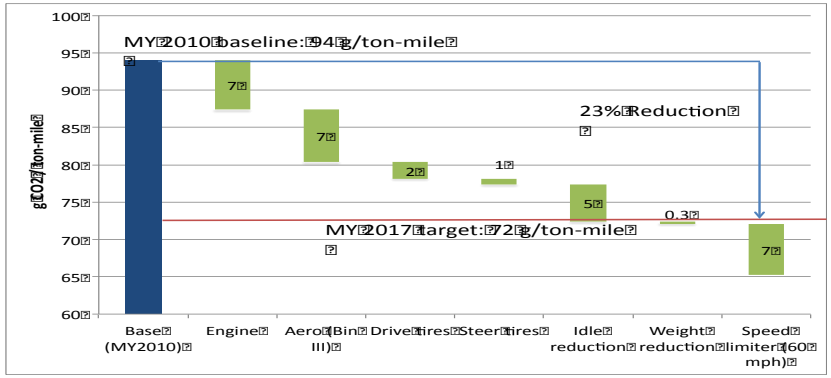


Source: Ricardo

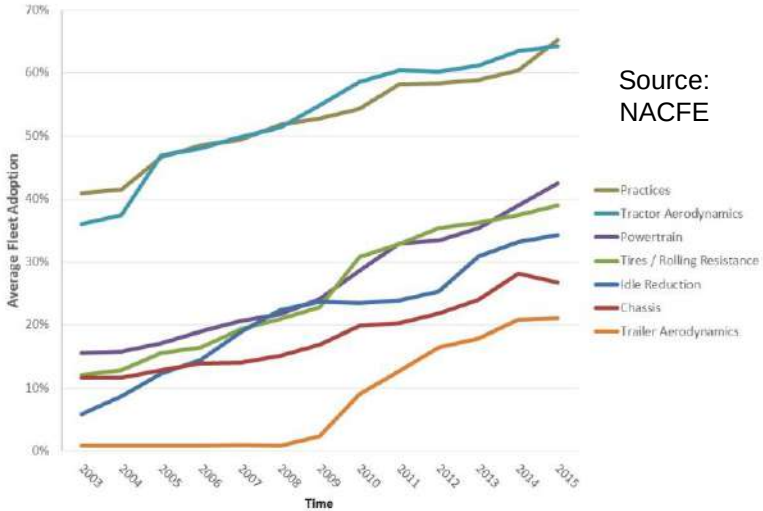
France



US



Truck Technology Adoption Level (US)



Source: NACFE

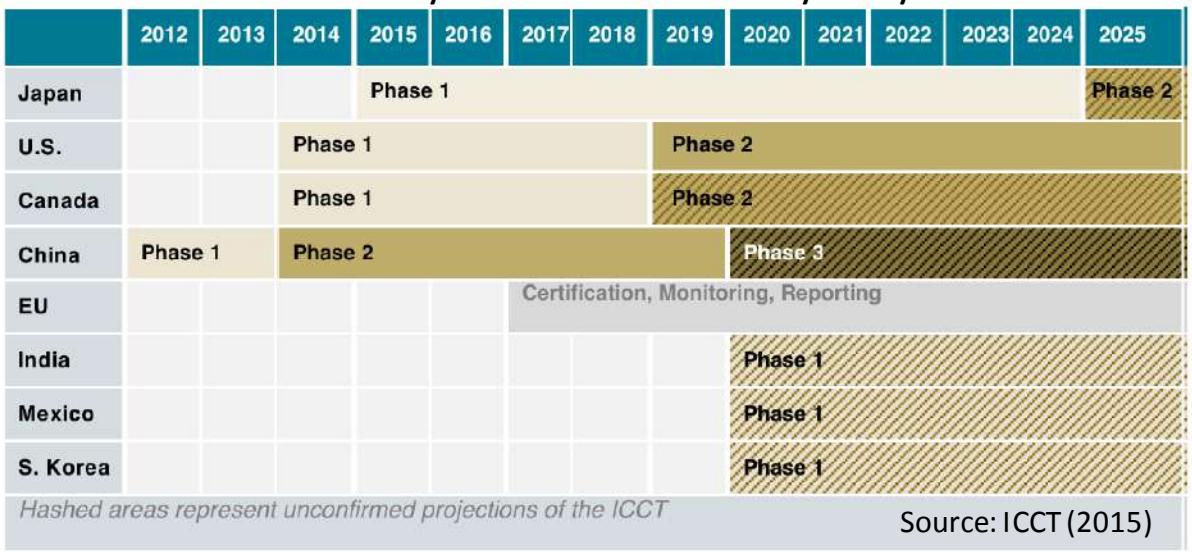
Retrofitting fuel saving devices

Government vehicle scrappage schemes

Global trade in second-hand trucks

Use of Fuel Economy Standards to Drive Efficiency Improvement

Fuel Economy Standards for Heavy Duty Vehicles

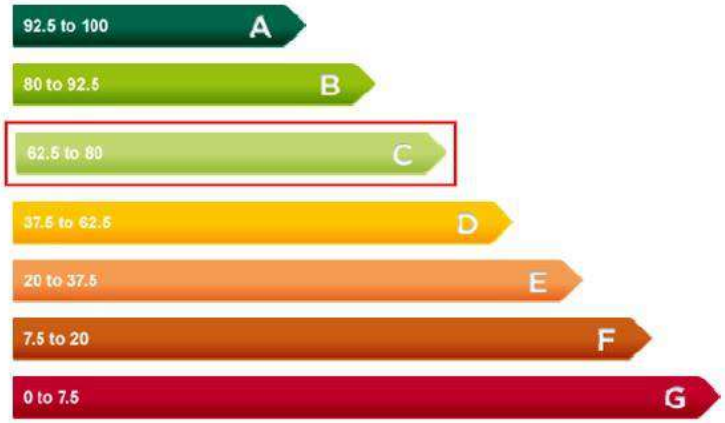


Source: ICCT (2015)

EU lagging

EEDI Ship Type/Size	Container, TEU 8,000+
EEDI (grams CO2 per tonne nautical mile)	13.719
EEDI Rating	2.693
Shippingefficiency.org Rating	

EEDI ship efficiency ratings



Improving the Aerodynamic Profiling of Individual Trucks and Platoons

Over cab spoiler

Teardrop

Cheetah

Fuel efficiency gains for improved aerodynamics:

'individual components: 0.5 – 3%'
(IEA, 2017)

Boat-tails

Trailer under-tray

Dolphin

Less benefit in developing countries where speeds are lower

truck platooning

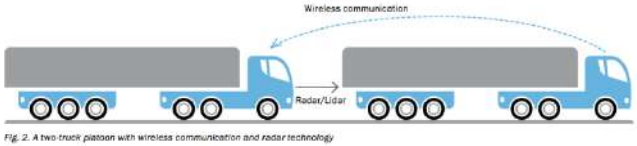


Fig. 2. A two-truck platoon with wireless communication and radar technology

European Platooning Challenge

Fuel efficiency gains for US Class 8 trucks:
Lead vehicle – 5.3%
Trailing vehicle – 9.7%

(Lammert et al, 2014)

EU long haul road freight

	% in platoons	% CO2 savings
2030	10	1
2050	40	4

IRU (2017)

More Fuel Efficient Truck Driving

With driver training and fuel performance monitoring: *typical 5-10% fuel efficiency gain*

driver training and incentives

Anti-idling devices
Adaptive cruise control
Predictive cruise control

telematic monitoring

vehicle checking and defect reporting

International Transport Forum
'*conservative scenario*'
25% of trucks driverless by 2040

US Postal Service:
28,000 rural delivery routes served by automated vans by 2025

IEA (2017): truck automation

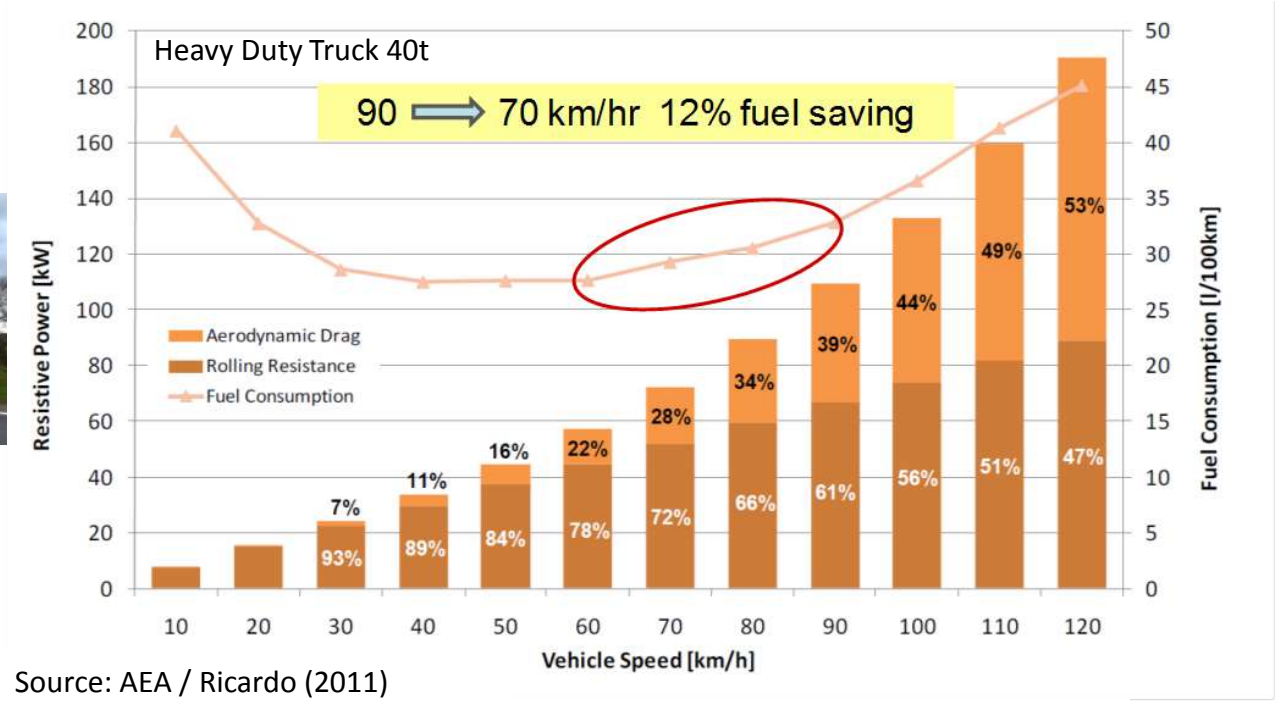
15-25% improvement in fuel efficiency

Roland Berger (2016): with truck automation

10% lower fuel consumption by US trucks than BAU by 2040

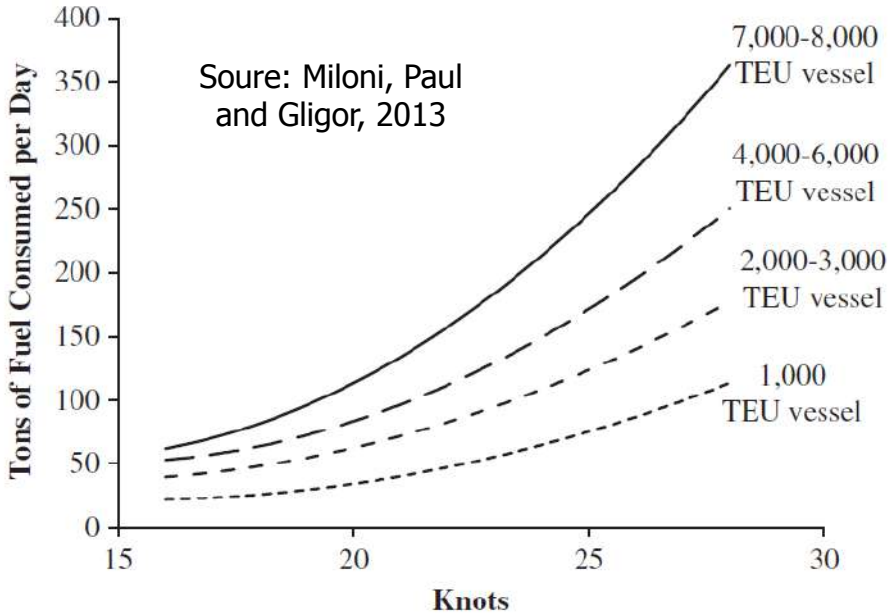
‘Down-speeding’ Freight Transport: *Energy Saving + CO_2 Reduction*

slow driving



Source: AEA / Ricardo (2011)

slow steaming



IMO (2014)

2007-2012

Average at-sea speed relative to design speed 12% lower

Average daily fuel consumption 27% lower

Five Sets of Decarbonisation Initiatives for Freight Transport

Reduce Demand for Freight Transport

Shift Freight to Lower Carbon Transport Modes

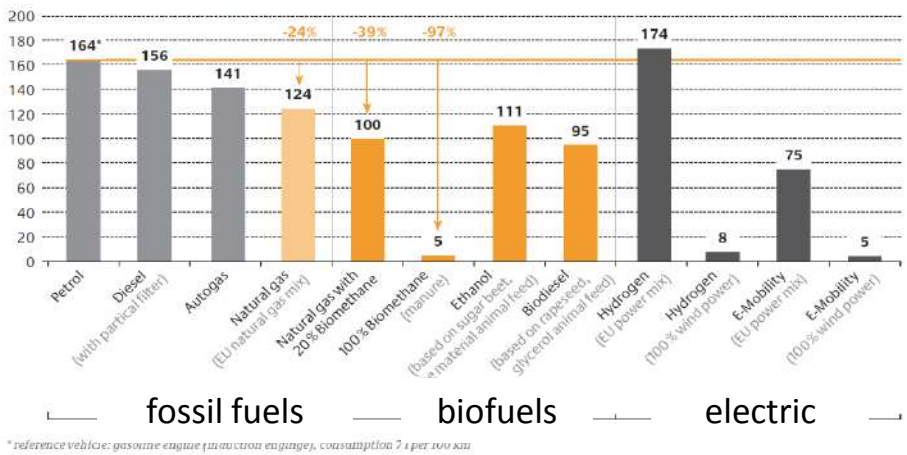
Optimise Vehicle Loading

Increase Energy Efficiency of Freight Movement

Reduce the Carbon Content of Freight Transport Energy

Switch to Cleaner, Low Carbon Energy

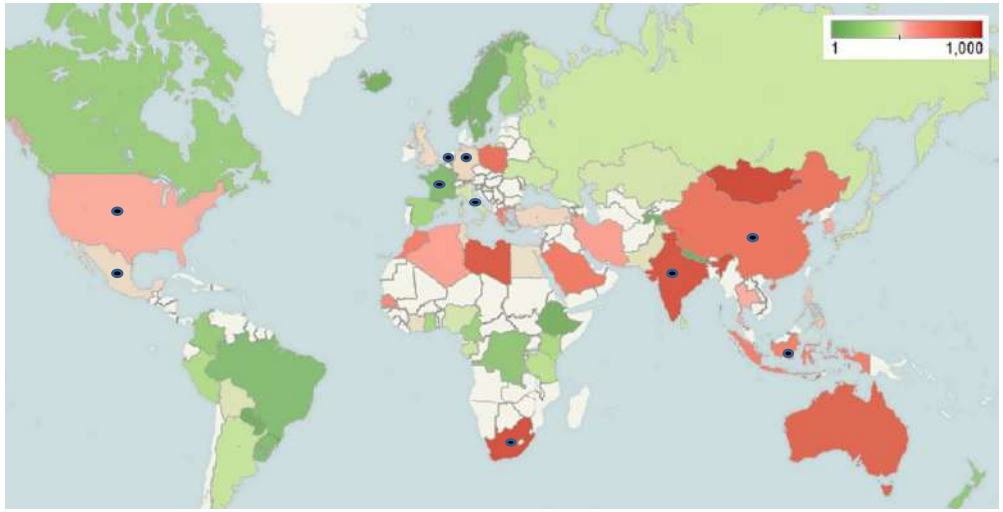
WTW CO_{2e} emissions



biofuel fuels: *slow uptake*

- uncertainty about net GHG impact
- limited supply of biofuels
- inter-sectoral competition for supplies
- lack of refuelling infrastructure
- methane leakage problem

Current CO_2 benefits of freight electrification?



Carbon intensity of electricity generation (gCO2 / kWh)

http://shrinkthatfootprint.com/electricity-emissions-around-the-world

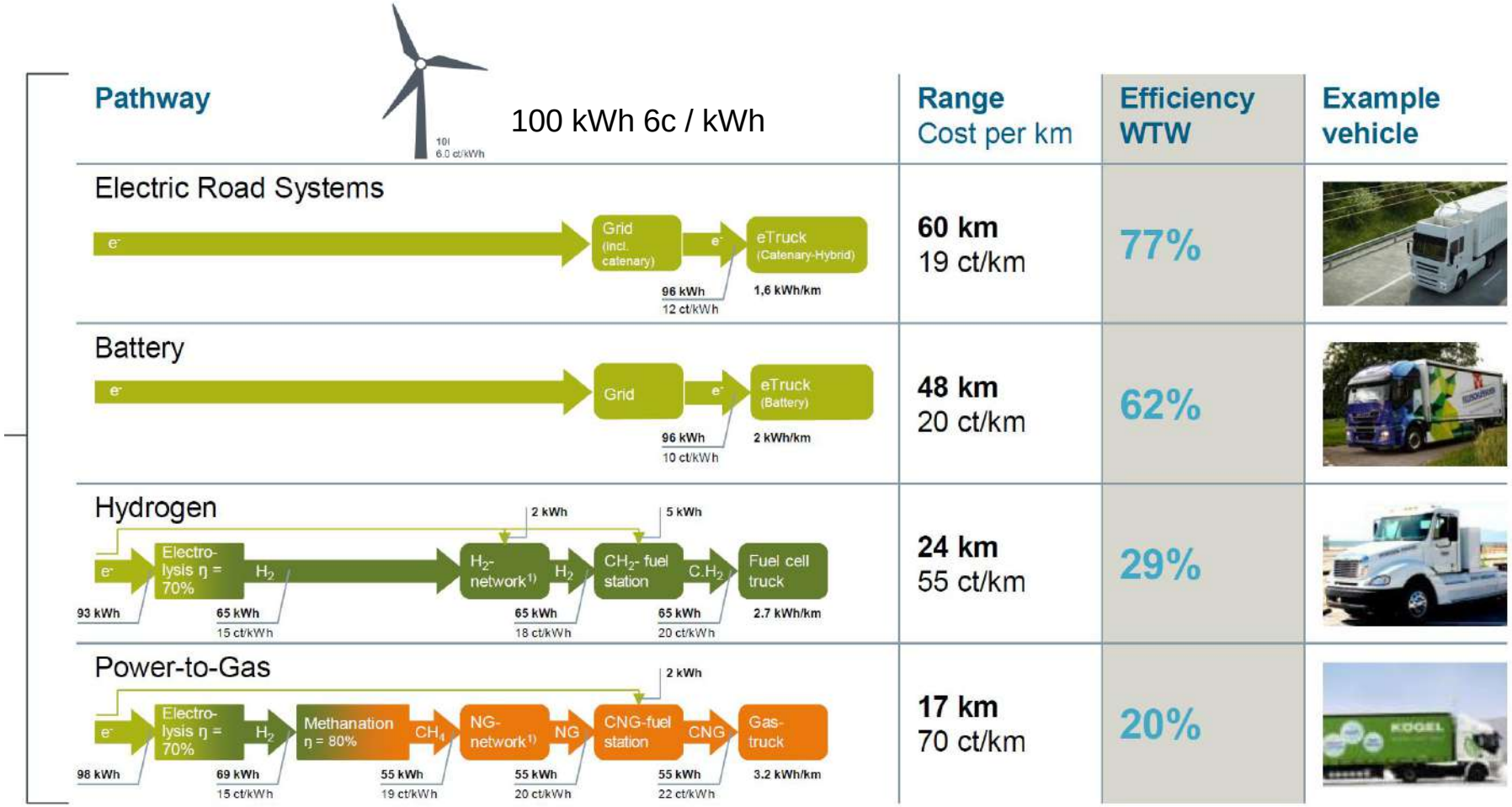
Short-term: *electrified rail*
local road delivery

- recharging infrastructure
- future battery performance
- E- vehicle price differential

Long term:
cold ironing of ships in port

electrified roads?

Energy Efficiency and Cost of Different Methods of Electrifying Long Haul Road Freight



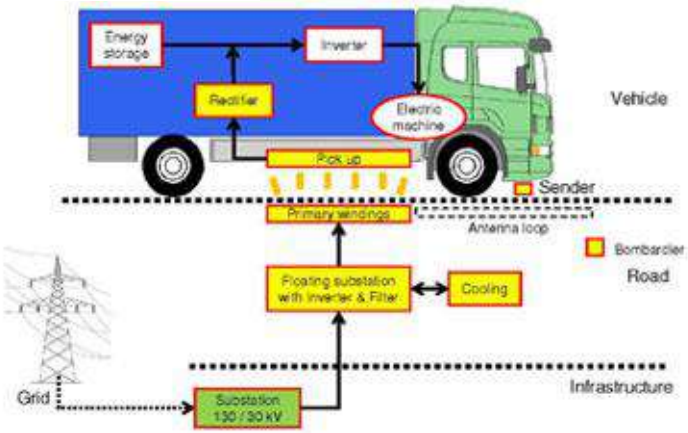
Source: German Ministry of Environment (quoted by Akerman, 2016)

electrified roads: Trials in Sweden, Germany and the US

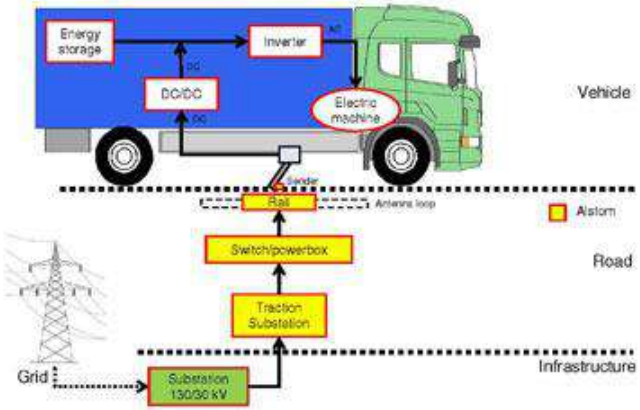
Electric Road System (ERS)

Catenary

Inductive

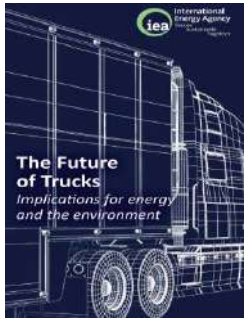


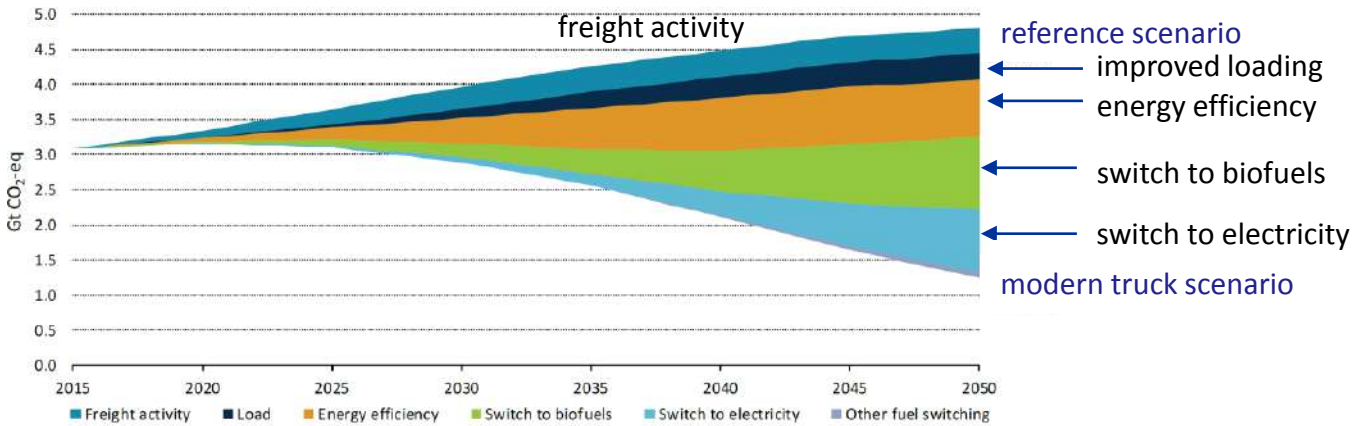
Slide-in rail



Assessing Carbon Savings from Efficiency Improvements and Switch to Alternative Energy

CO_{2e} emissions from road freight transport: reference (i.e. baseline) scenario vs modern truck (i.e. low carbon) scenario





source: IEA (2017)

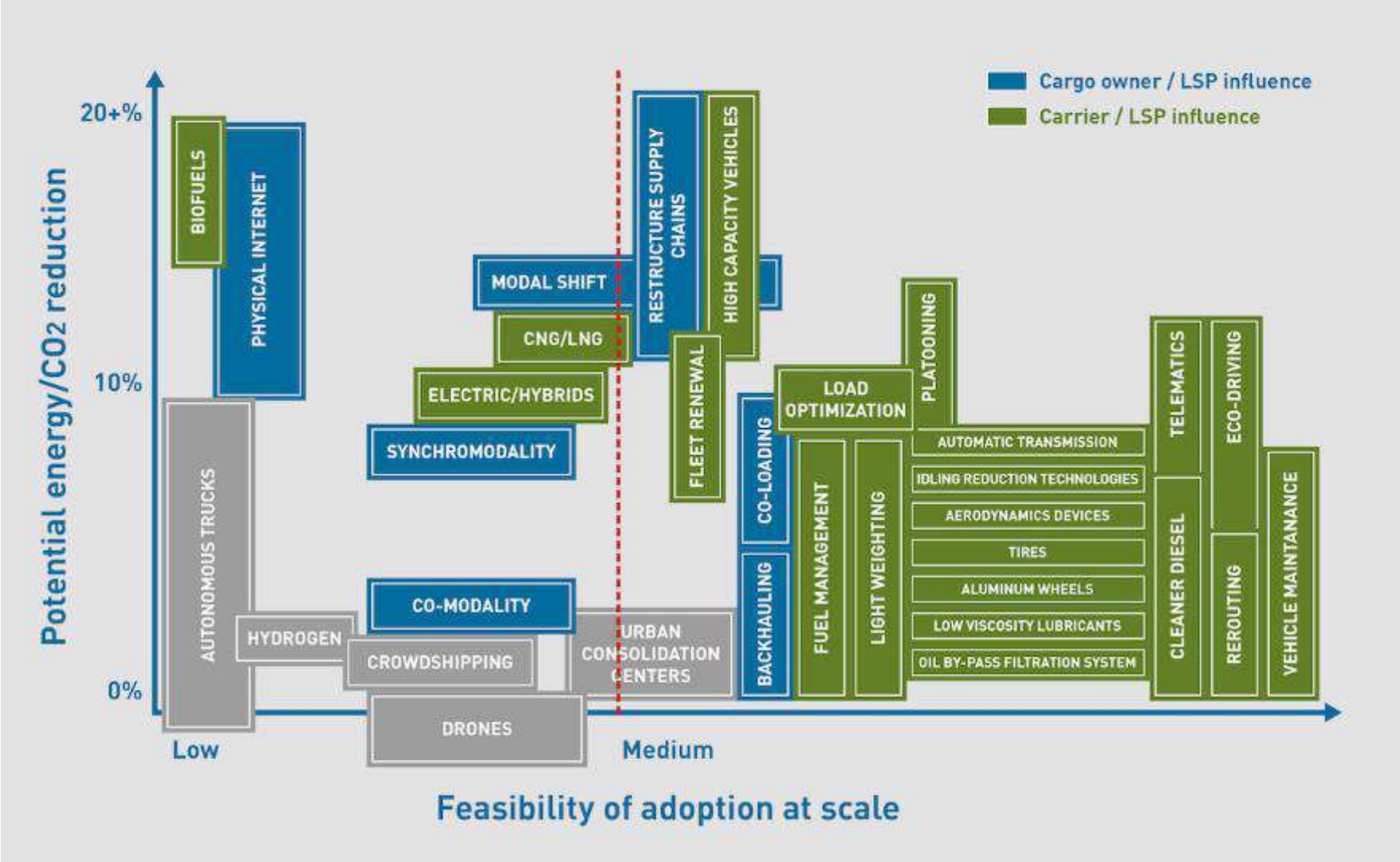
IRU (2017) '*Commercial Vehicle of the Future*'

Long haul	2030	2050	Comment	cumulative reduction 2030	cumulative reduction 2050
Powertrain efficiency (diesel)	10%	15%	Includes engine, transmission, auxiliaries,...	10.0%	15.0%
Gas vehicles	2%	4%	Minimise methane emissions	11.8%	18.4%
Renewable fuels (gas & liquid)	2%	24%	IEA general target, large increase in 2nd generation biofuels needed. Includes biogas.	13.6%	38.2%
Driver training and driver assistance systems	6%	8%	Includes ACC, PCC,...	18.8%	43.2%
Reduce max speed	2%	2%	To 80 km/h	20.4%	62.8%
ITS & communications	1%	4%	Platooning	21.2%	46.5%
Aerodynamics	6%	10%	Important contribution expected from trailers and semi-trailers, including solutions developed in the TRANSFORMERS Project	25.9%	51.3%
Tyres	7.5%	12.5%	Includes super singles	31.5%	57.4%
Lightweighting	0%	0%	Compensated by increased weight from other measures	31.5%	57.4%
Pavement	3%	3%	Improved rolling resistance (maintenance or new pavement)	33.5%	58.7%
Reduce empty running, improve load factors, digitalisation	2%	10%	Rollout of coordinated system needed	34.8%	62.8%
More flexibility in weights and dimensions (including EMS)	3.5%	7.5%	Allowance of EMS in cross border transport in the EU	37.1%	65.6%
More renewables – hybridisation (2030)/electrification (2050) ?????	3%	37%	For 2050, most from full electrification ???????	**39.0%**	**78.2%**

new TESLA truck
a gamechanger?

- battery powered
- 300 mile range
- autonomous
- Platooning-ready

Overview of Decarbonisation Options for the Freight Transport Sector

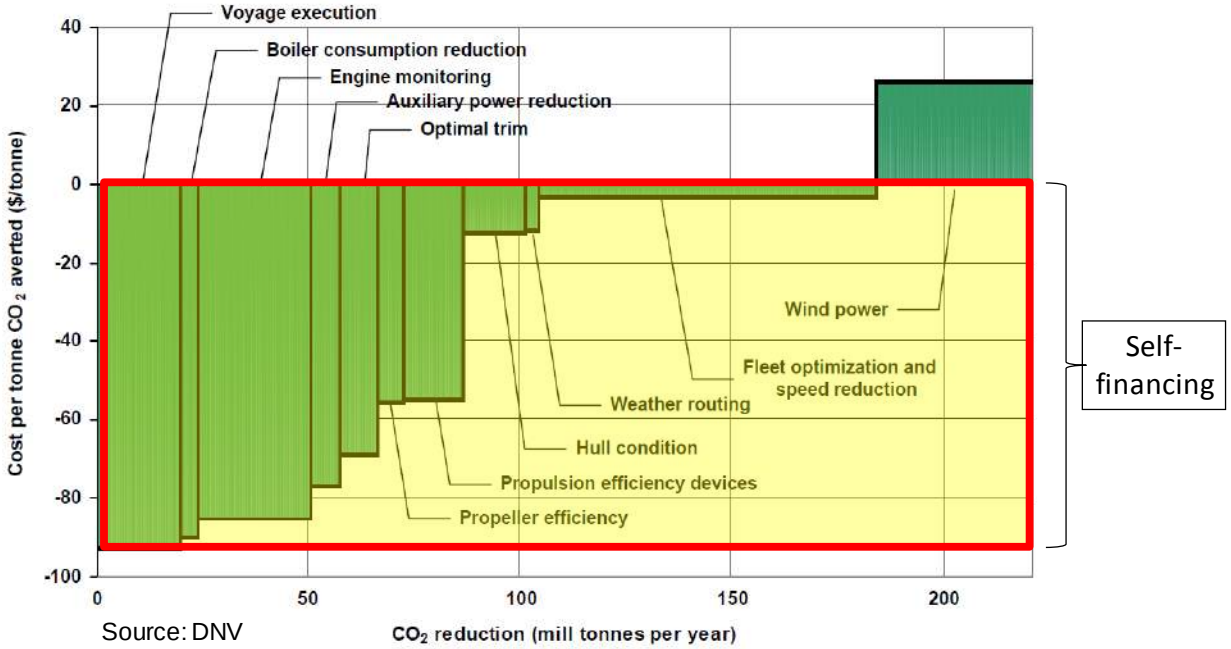


Source: Smart Freight Centre 'Solutions Map' based on IEA and Prof David Cebon

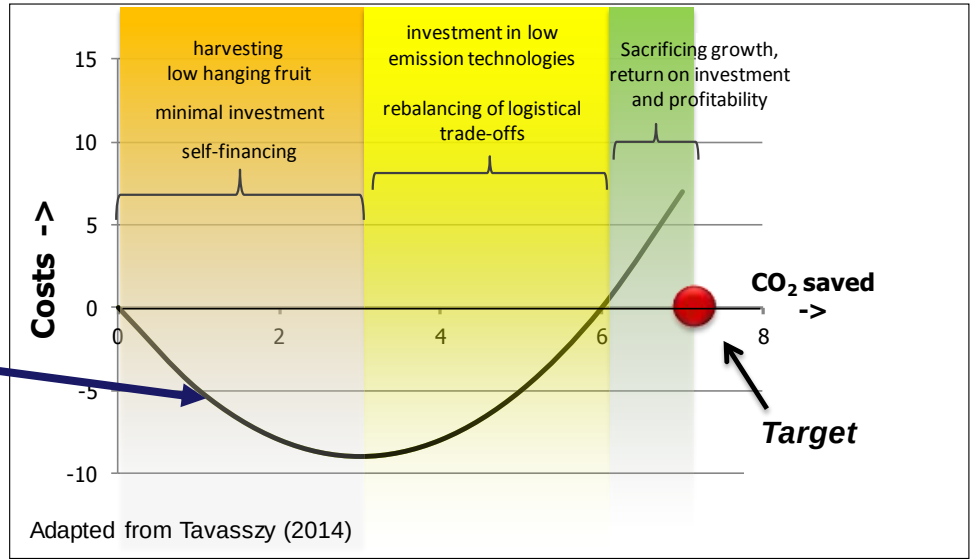
Economics of Decarbonising Freight Transport

close correlation between cutting carbon emissions and saving money

Marginal Abatement Cost Analysis of Shipping Decarbonisation Measures



Source: DNV



Adapted from Tavasszy (2014)

risk of rebound effects

lower cost stimulating freight traffic gro

offsetting CO_2 savings

Green Freight Programs

May 2015

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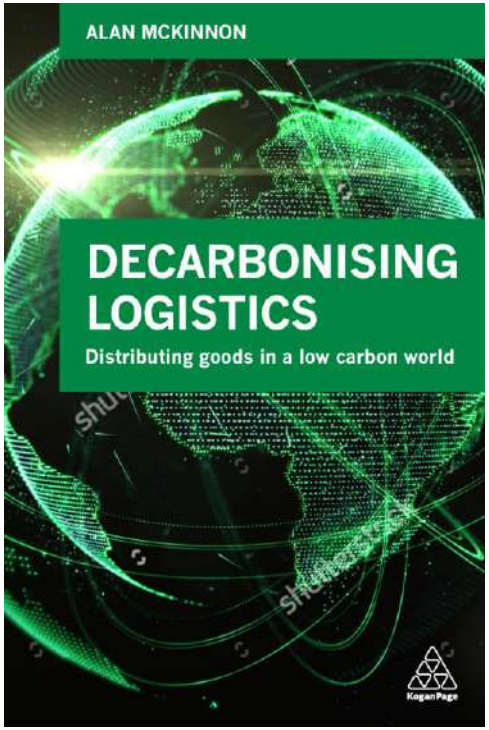
Forthcoming book



References to reports, papers and other data sources used in this presentation can be found at:
http://www.alanmckinnon.co.uk/newslayout.html?IDX=773&b=74&q=2017