VOLTA CHEM

Electrification of the Chemical Industry

Deep decarbonisation of the Dutch heavy industry through electrification of the production of basic materials and transportation fuels

Toon van Harmelen, Clemens Schneider, Yvonne van Delft, Robert de Kler, Mathieu Baas, Vincent Kamphuis

Powered by: TNO innovation for life, ECN, Wuppertal Institute for Climate, Environment and Energy

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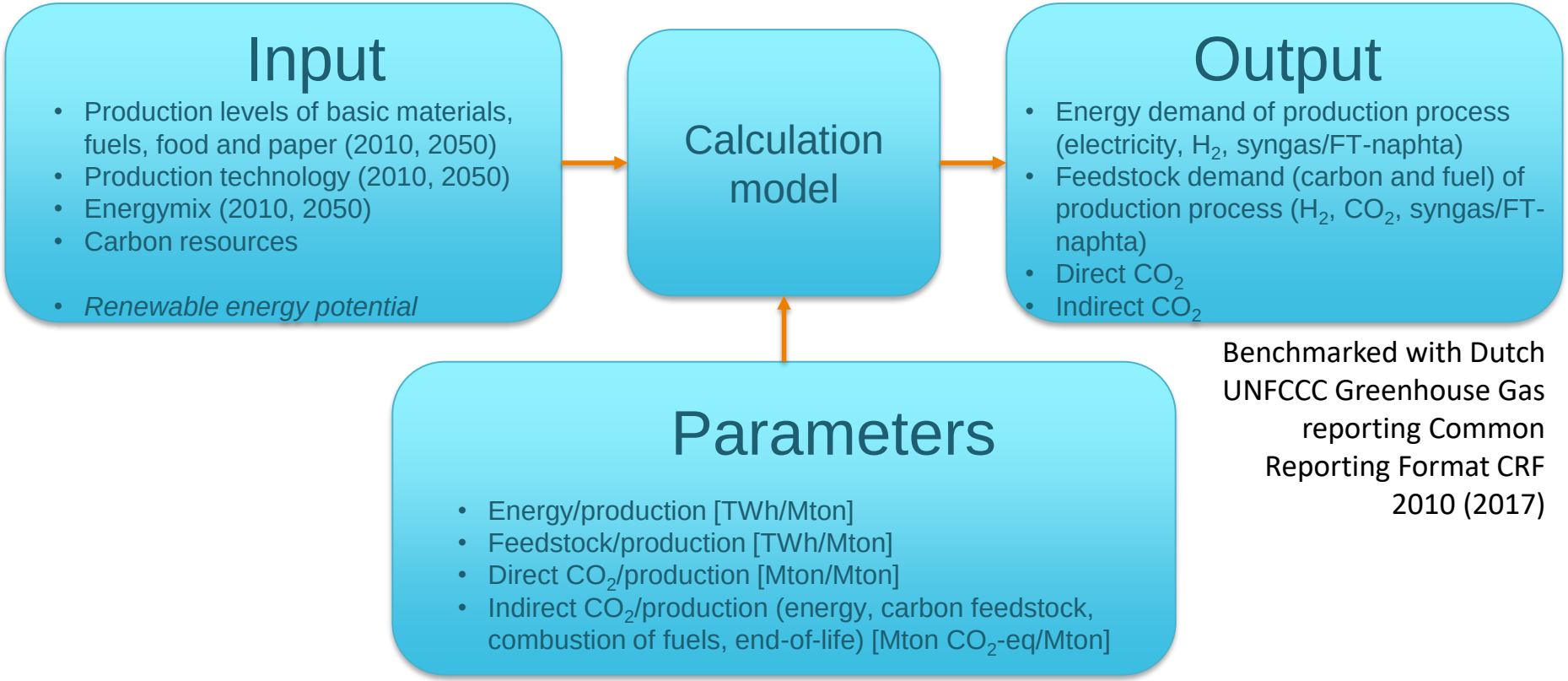
Objective

To explore deep decarbonisation scenarios for the demand of the Dutch heavy industry in 2050, through electrification of the production of basic materials and transportation fuels

- identify the technical feasibility,
- required feedstock and energy potentials and
- pros and cons of different electrification pathways

Model set-up



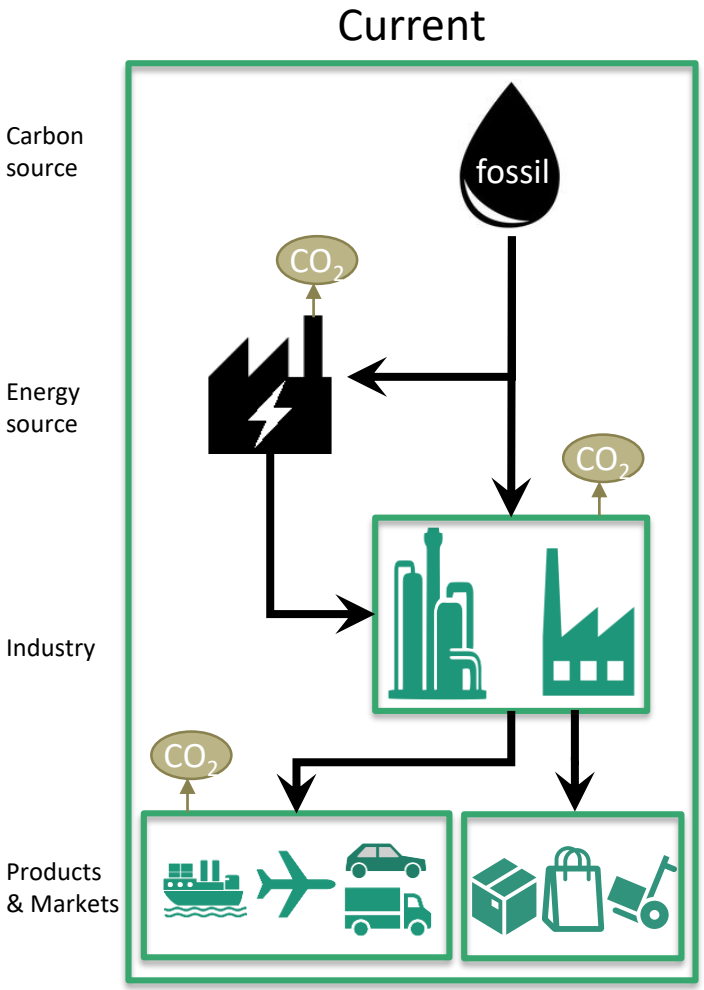
Benchmarked with Dutch UNFCCC Greenhouse Gas reporting Common Reporting Format CRF 2010 (2017)

Based upon: Decarbonising the energy intensive basic materials industry through electrification - Implications for future EU electricity demand, Stefan Lechtenböhmer et al (2015, Wuppertal Institute & Univ of Lund)

Methodology & assumptions

- Life cycle CO_2 to 0: direct fossil based CO_2 emissions at production, use phase, end-of-life of products (also of exports)
- What-if electrification scenarios sketching three distinct technology based pathways
- Modest volume growth, no structural changes (“High growth” scenario from Prosperity & environment, CPB/PBL 2015)
- Using North Sea wind power potentials, incl. 23% battery storage losses for maintaining security of supply:
  - NL: 34 GW ~ 130 TWh (PBL, 2011)
  - North Sea: 250 GW ~ 1000 TWh (Energy Odessey)
  - 90% one-way battery efficiency (projected battery efficiency, TNO 2018)

Current situation



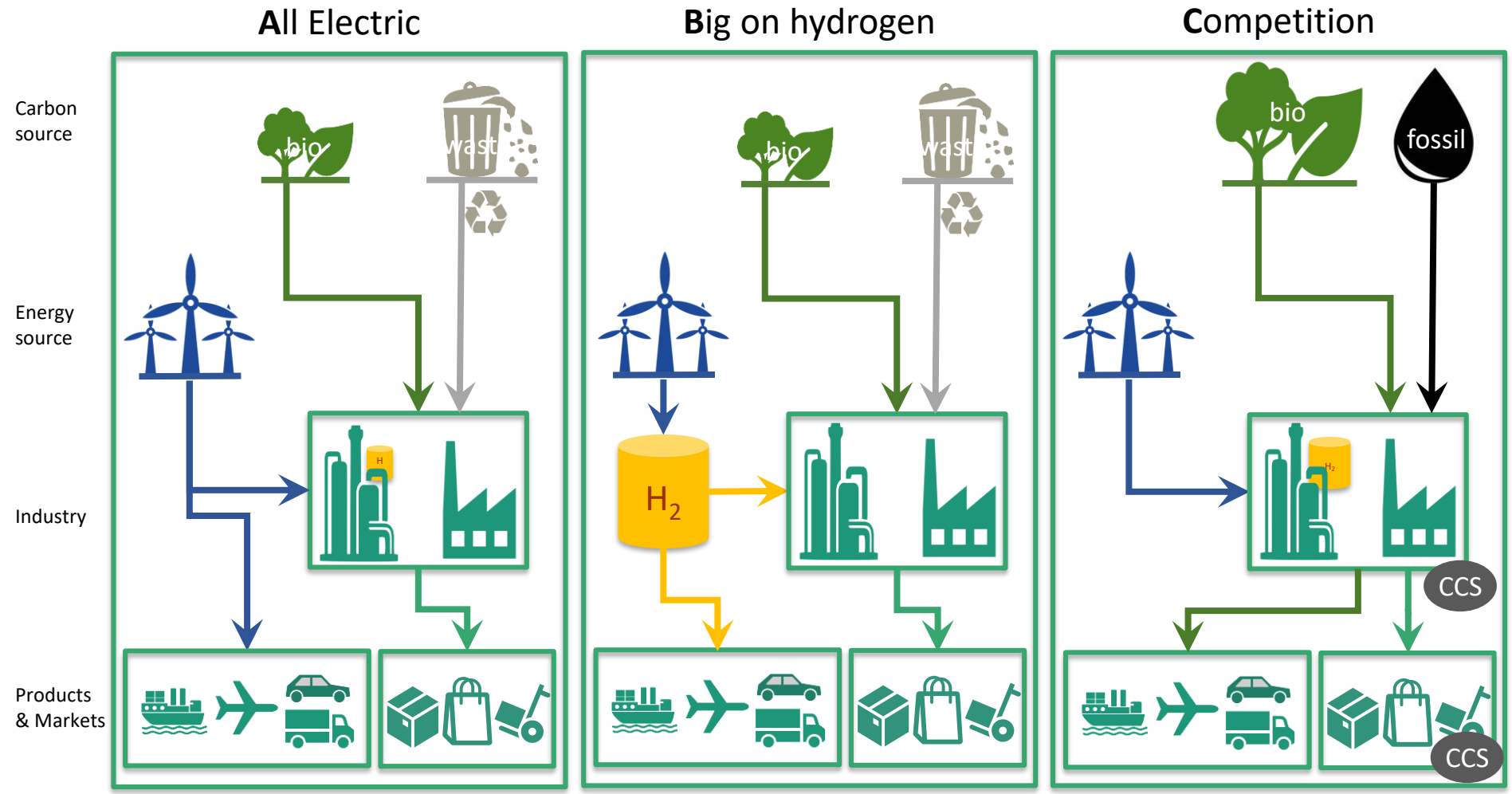
Products

- Basic Chemicals
  - Olefins
  - Ammonia
  - Chlorine
- Metal
  - Iron & steel
  - Aluminum
- Food
- Minerals
  - Glass & ceramics
  - Cement
- Paper & pulp

Transport Fuels

- Road Transport
- Aviation
- Navigation

What-if electrification scenarios A, B and C



What-if scenarios:
Three distinct technological pathways

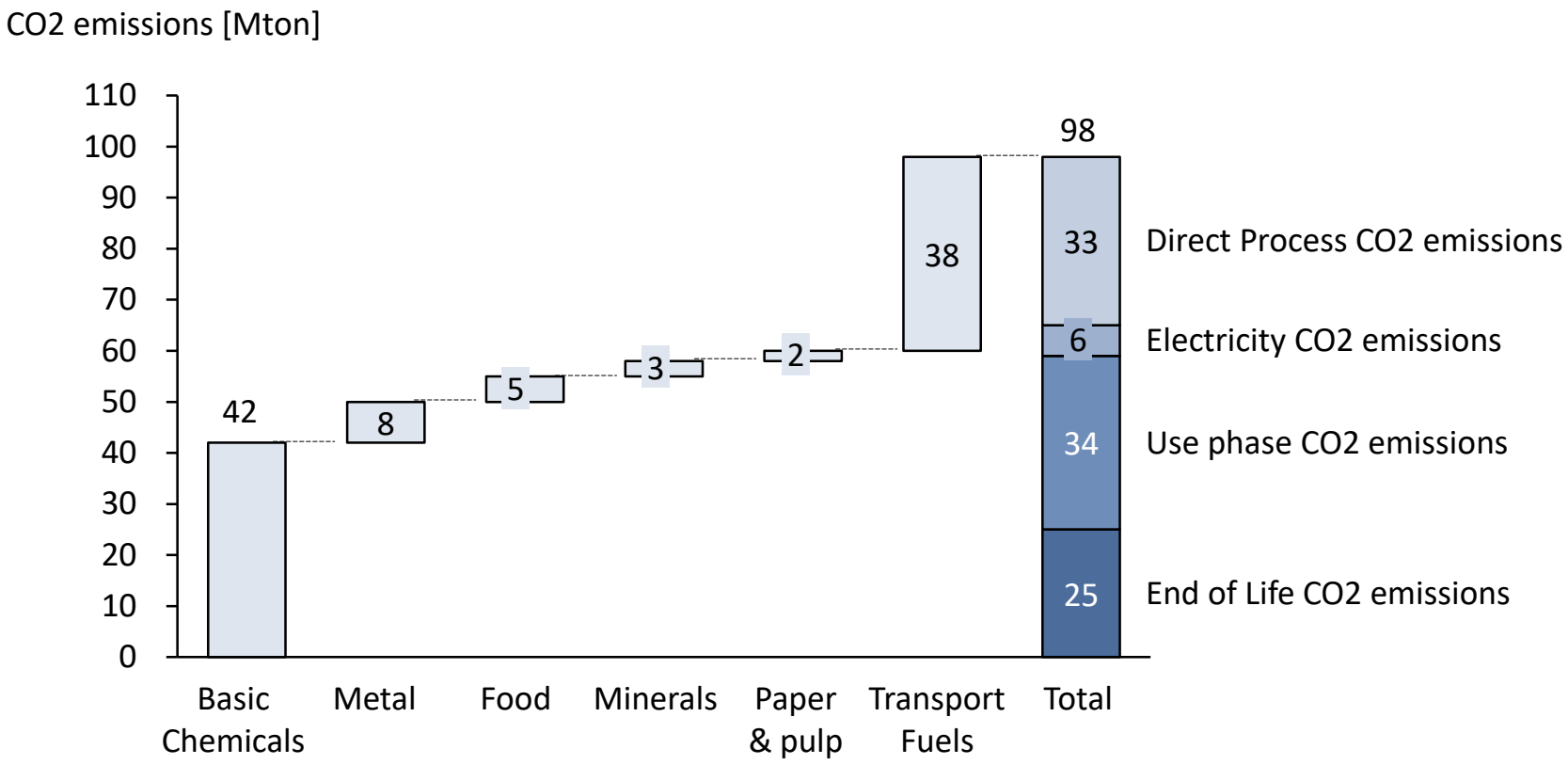
Scenario	Current situation	A. All electric	B. Big on hydrogen	C. Competition
Short description	**Production is largely fossil based**	**Renewable electricity as energy carrier in industry and transport.** Maximal direct electrification with storage issues. Refineries are closed	**Hydrogen as final energy carrier for transportation and industry,** produced with conversion losses by renewable electricity**.** Refineries are closed. Add H2 infrastructure	**A mix of energy carriers, renewable electricity (indirect electrification, hydrogen), fossil fuels with CCS and bio(syn)fuels.** Add CO2 infrastructure
Carbon source and CO2 emissions	Fossil based energy and feedstock, **high CO2 emissions**	Partly closed carbon cycle, waste & bio (growth) used as feedstock (olefins), **near zero CO2 emissions**	Partly closed carbon cycle, waste & bio (growth) used as feedstock (olefins), **near zero CO2 emissions**	Crude oil for olefins and coal for steel combined with CCS; scarce bio based synfuels used for transportation and small sectors, **near zero CO2 emissions**
Leading stakeholders	Gas and petrochemical industry	Power sector (DC grid)	Gas sector (H2 grid)	Petrochemical industry and others
Demand projection	Product and service demand projections are from the PBL scenario high growth, combined with assumed high energy efficiency improvements up to a factor 2			

Technological options by subsector and scenario

Sector	Subsector	Product	Processes			
			Current situation	A. All electric	B. Big on hydrogen	C. Competition
Basic chemicals	Olefins (High Value Chemicals)	Ethylene, propylene, other	Current crude oil based processes	Bio (for growth) and waste based MTO/MTA are used for olefin production	Bio (for growth) and waste based MTO/MTA are used for olefin production	Use crude oil refining and naphta and gasoil steam cracking and residue gasification via MTO to produce olefins/aromatics (CCS waste incineration)
	Chlorine		Current electrical process	Current electrical process	Current electrical process	Current electrical process
	Ammonia	Fertilizer	Current natural gas based processes	Direct electrical ammonia synthesis	Indirect electrical ammonia synthesis via H2	Current gas based, decarbon electricity + CCS
Transport	Freight road	Diesel	Combustion engines	Electric vehicles	H2 fuel cells	Biobased methanol
	Passenger road	Gasoline, diesel, CNG and electricity	Combustion engines	Electric vehicles	H2 fuel cells	Biobased methanol
	Aviation	Kerosene	Combustion engines	Electric airplanes	H2 fuel cells	Biobased kerosene
Oil refinery	Basic chemicals		Crude oil refining	None	None	Crude oil for feedstock
	Fuels		Crude oil refining	None	None	None
Metal	Iron & steel:	Primary steel	Blast oxygen furnace	Electrowinning	Direct reduction H2 + EAF	HISARNA or TGR + Carbon Capture
		Secondary steel	EAF, Secondary steel from scrap	EAF, Secondary steel from scrap	EAF, Secondary steel from scrap	EAF, Secondary steel from scrap + CCS
	Aluminium		Current process	Current process	Current process	Current process
Minerals	Glass	Container glass, flat glass, glass fibre	Current processes	Electric oven	H2 oven	Synthetic CH4 oven + CCS
	Cement	Cement	ENCI	None	None	None
	Lime	Lime	No lime production	None	None	None
Food		Milk powder, potato & sugar represent sector	Steam boilers	Heat pumps + compression + HT storage, breakthroughs	Heat pumps + compression + H2/fuel cells, fuel mix change	Biogas BAT, decarbon electricity
Paper & pulp		Paper	Steam boilers	Heat pumps + compression + HT storage, breakthroughs	Heat pumps + compression + H2/fuel cells, fuel mix change	Biogas BAT, decarbon electricity

Results

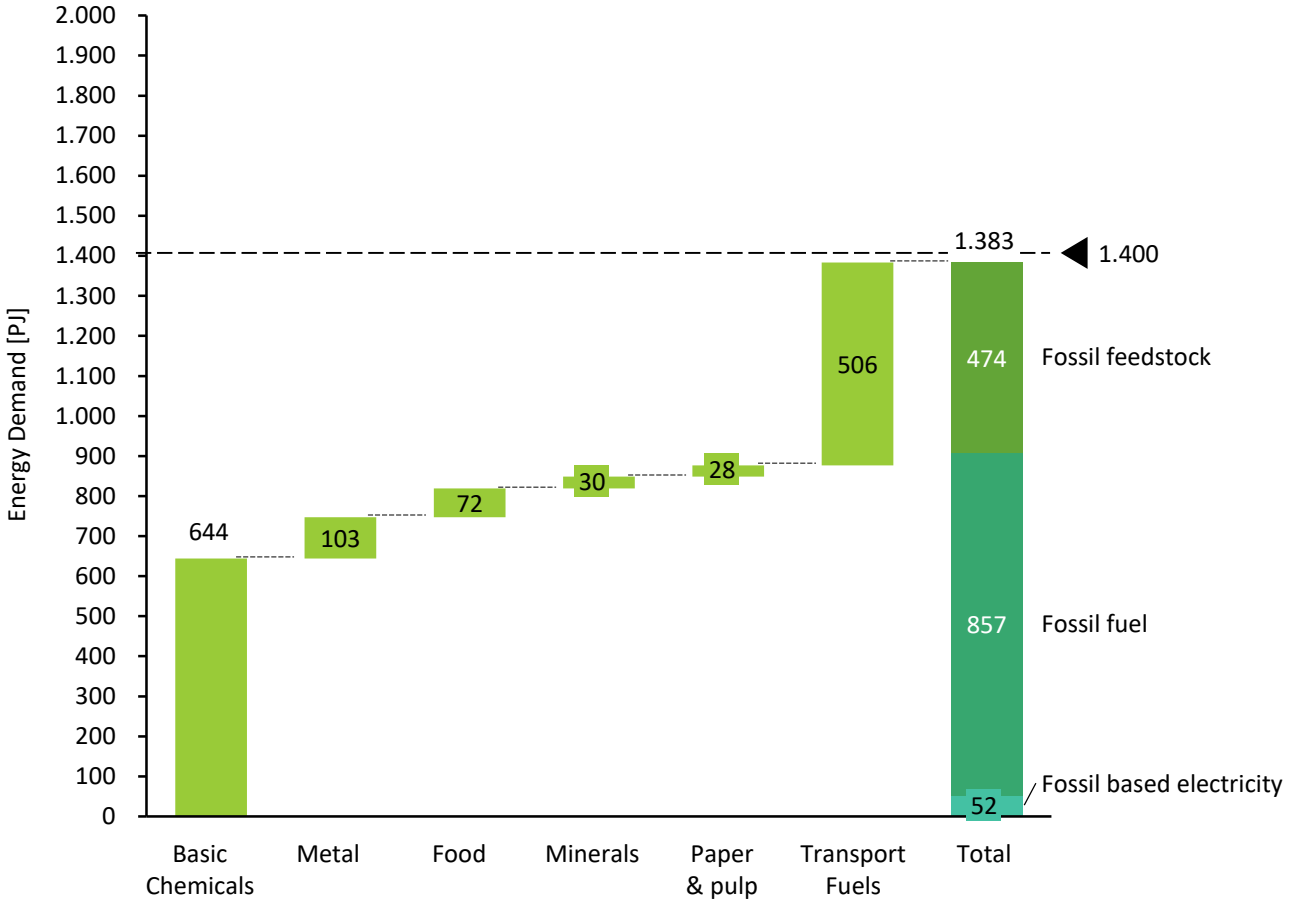
Current domestic CO_2 emissions (2010)



Basic chemicals (incl. export) and transport (excl. export) are dominant

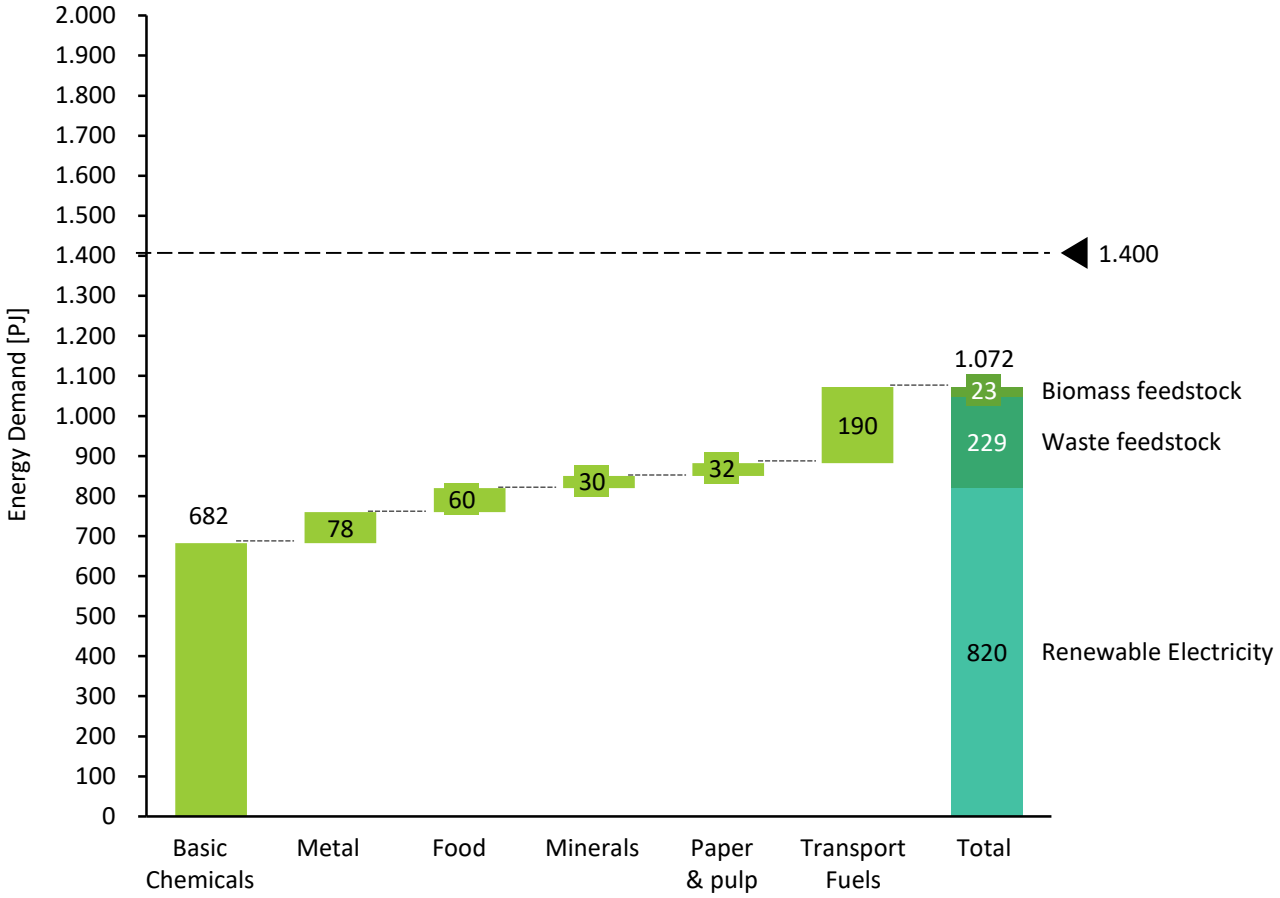
Life cycle CO2 including exports are comparable to total Dutch GHG emission (219 Mton)

Current situation



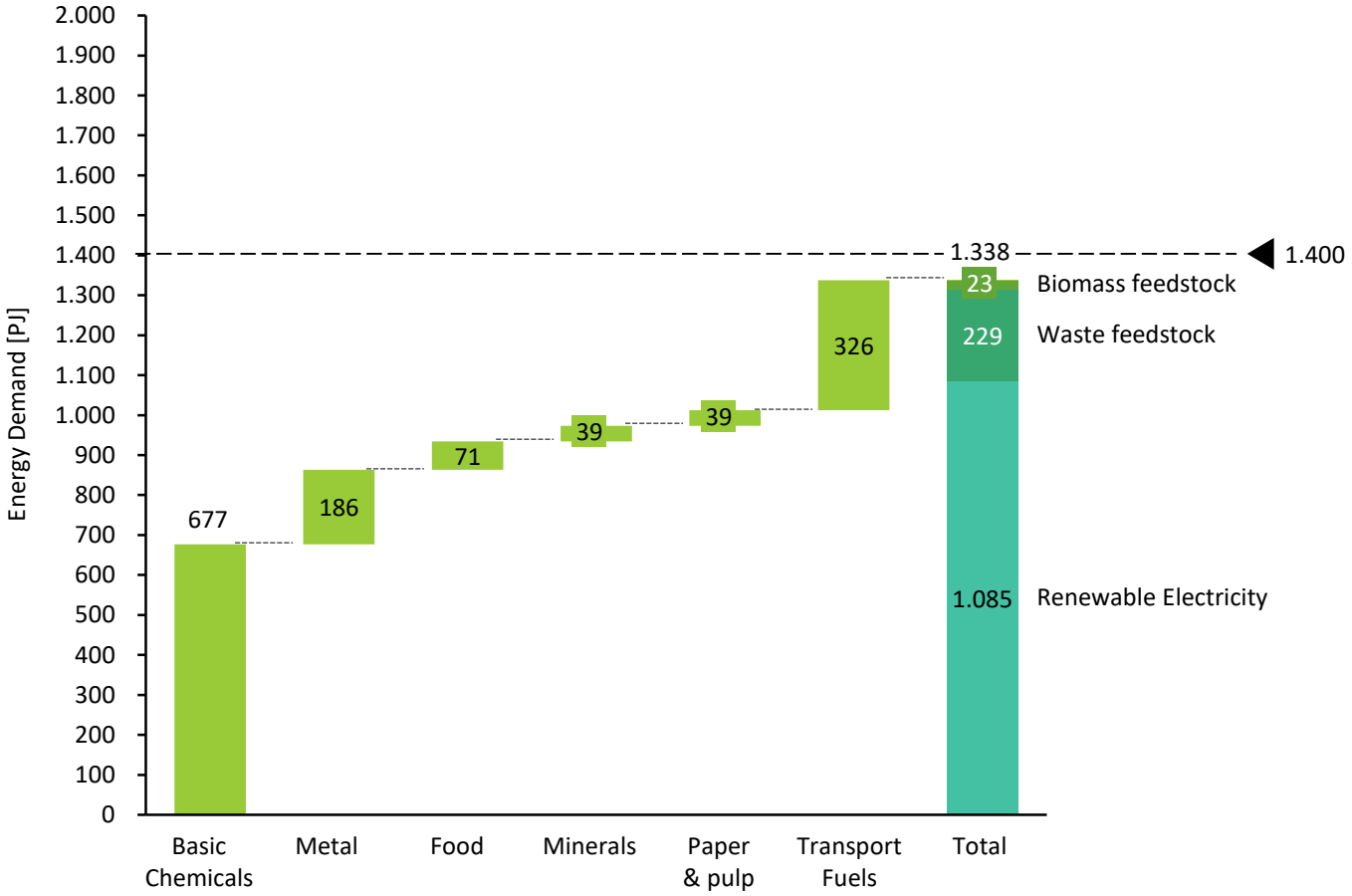
Energy and feedstocks almost completely fossil based

2050 Scenario All electric



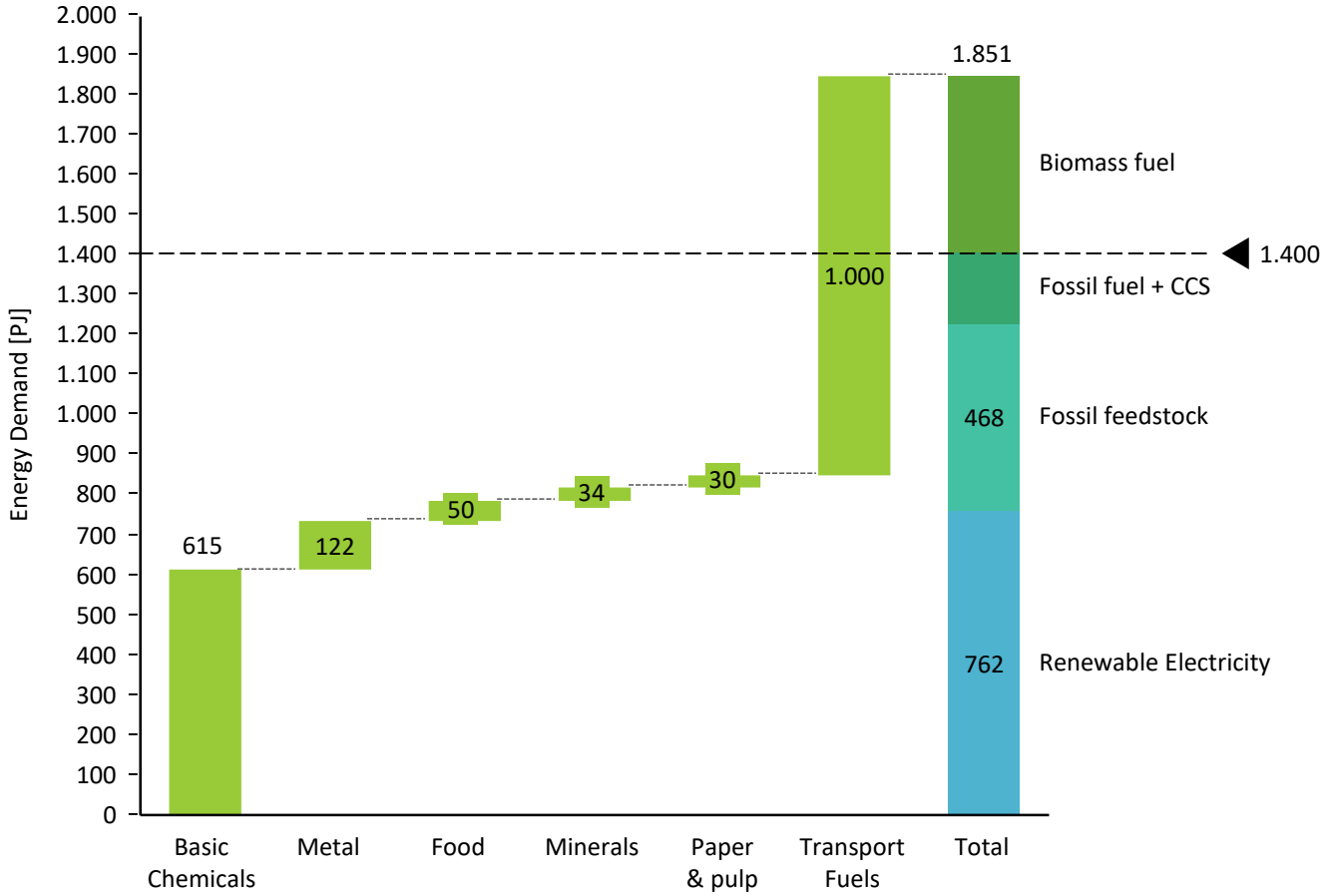
Direct electricity reduces energy demand with 20%; 2x NL North Sea wind, 25% total NS; completely fossil independent

2050 Scenario Big on hydrogen



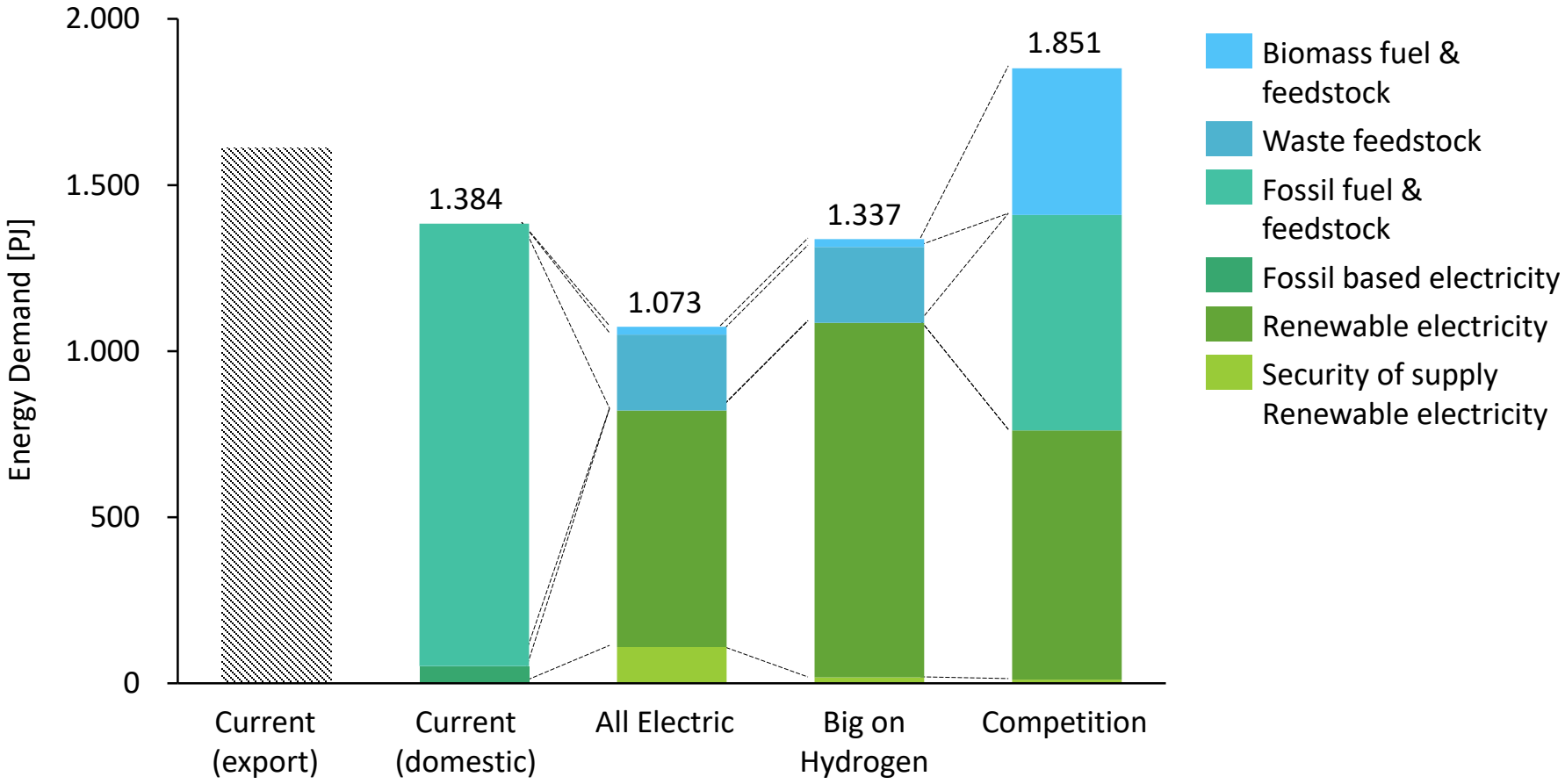
Indirect electricity via hydrogen results in a more or less stable energy demand, completely fossil independent

2050 Scenario Competition



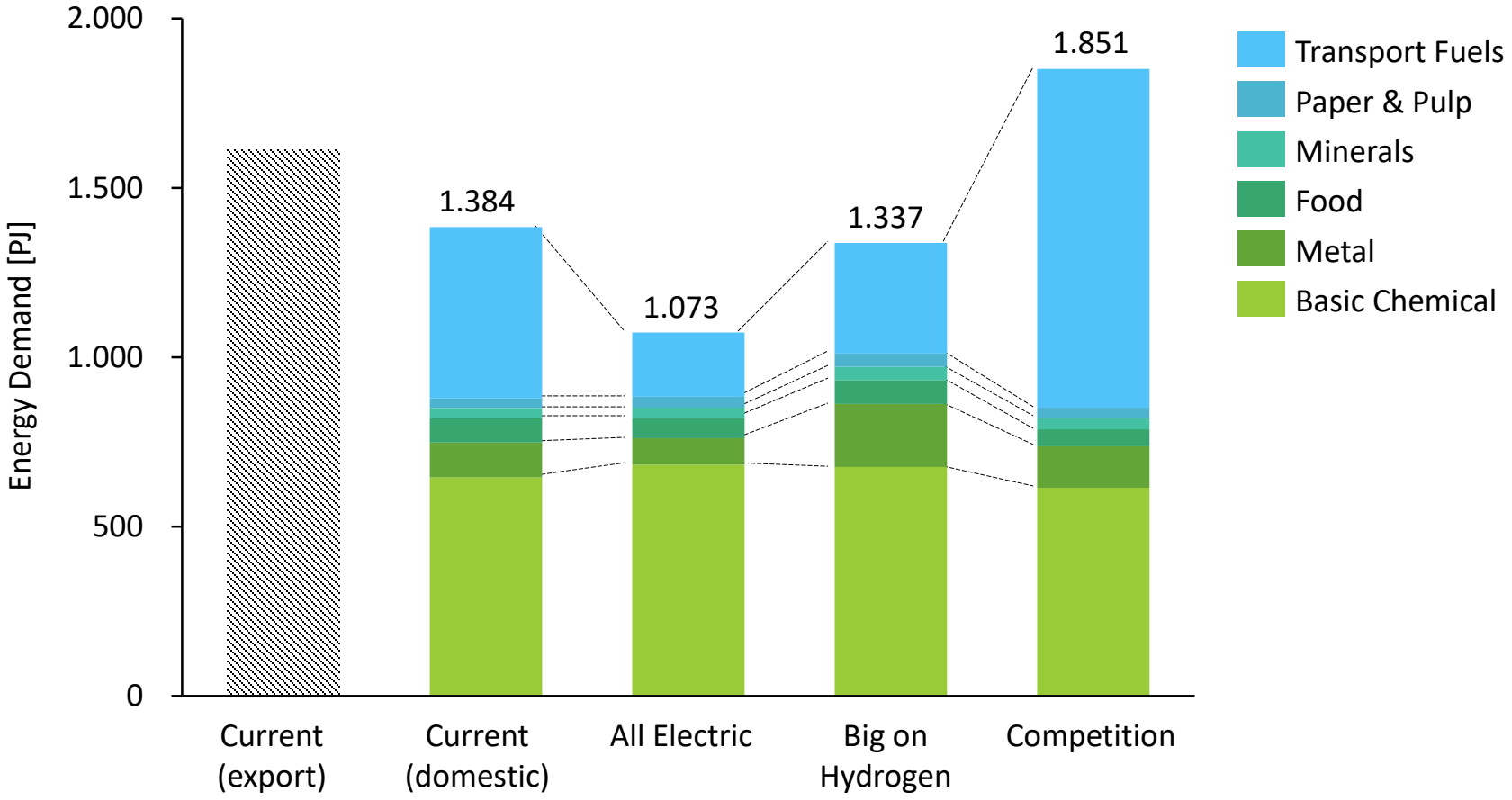
Increase of energy demand with 30%; biomass potential ~ 2 x NL; same electricity potential; crude oil and CCS needed

2050 Primary energy demand



North Sea wind potentials needed up to 2,5x NL North Sea wind, 30% total NS; C fossil dependent, biomass potential 2x NL

2050 Primary energy demand per sector



Sweet spots: All electric based road transport & steel, hydrogen based basic chemicals, bio in aviation?

Conclusions

- It is theoretically feasible to reduce life cycle CO_2 emissions by different electrification pathways to near 0 in 2050;
- 1,5–2,5x the Dutch wind energy potential on the North Sea is needed for transport (excl. bunkers) and heavy industry (incl. plastic export);
- Scenario All electric and Big on hydrogen are fossil fuel independent, Competition - relying partly on conventional technology with CCS - is not;
- Each scenario needs its own infrastructure with its challenges;
- A favorable scenario is likely a combination:
  - A. direct electrification in road transport, steel & minerals;
  - B. hydrogen in basic chemicals;
  - C. renewable alternatives in aviation, navigation and food & paper

Thank you for your attention

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