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REACHING NET-ZERO: SCENARIOS AND REGULATION TO RETHINK SECTOR COUPLING

MICHAEL G POLLITT AND CHI KONG CHYONG
(CERRE & UNIVERSITY OF CAMBRIDGE)

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SCOPE AND SCENARIOS

SESSION 1

OUTLINE OF THE PRESENTATION

1. **Scope and goals** of the study
2. **State-of-the-art energy system model** for net zero scenario and policy analysis
3. **Main results**: Net Zero (NZ) baseline scenario & variations
4. **Conclusions**
5. Debate **(Q&As)**

SCOPE AND GOAL(S) OF OUR STUDY

RESEARCH QUESTIONS

1. Sources of flexibility of gas and electricity in deep decarbonisation
2. Complementary dimensions and trends of different energy sources and vectors

OBJECTIVES

1. Re-model relevant long-term scenarios
2. Propose regulation to build the first blocks of sector coupling

WHAT IS SECTOR COUPLING?

SECTOR COUPLING, or energy system integration, is commonly understood as **integrating the energy consuming sectors** (such as buildings, transport, and industry) and **optimising them with the energy supply sector.**

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SECTOR COUPLING, or energy system integration, is commonly understood as **integrating the energy consuming sectors** (such as buildings, transport, and industry), and **optimising them with the energy supply sector.**

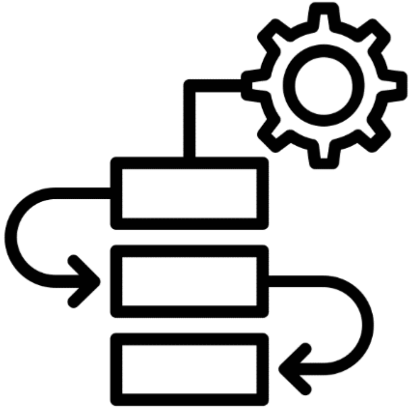
Our core research focuses on **coupling between electricity and gas supply systems,** taking into account **explicitly** their joint interactions with the energy consuming sectors and key end-use technologies.

WHAT IS SECTOR COUPLING?

- We consider sector coupling **technologies**
  - P2X
  - Hybrid heat pumps

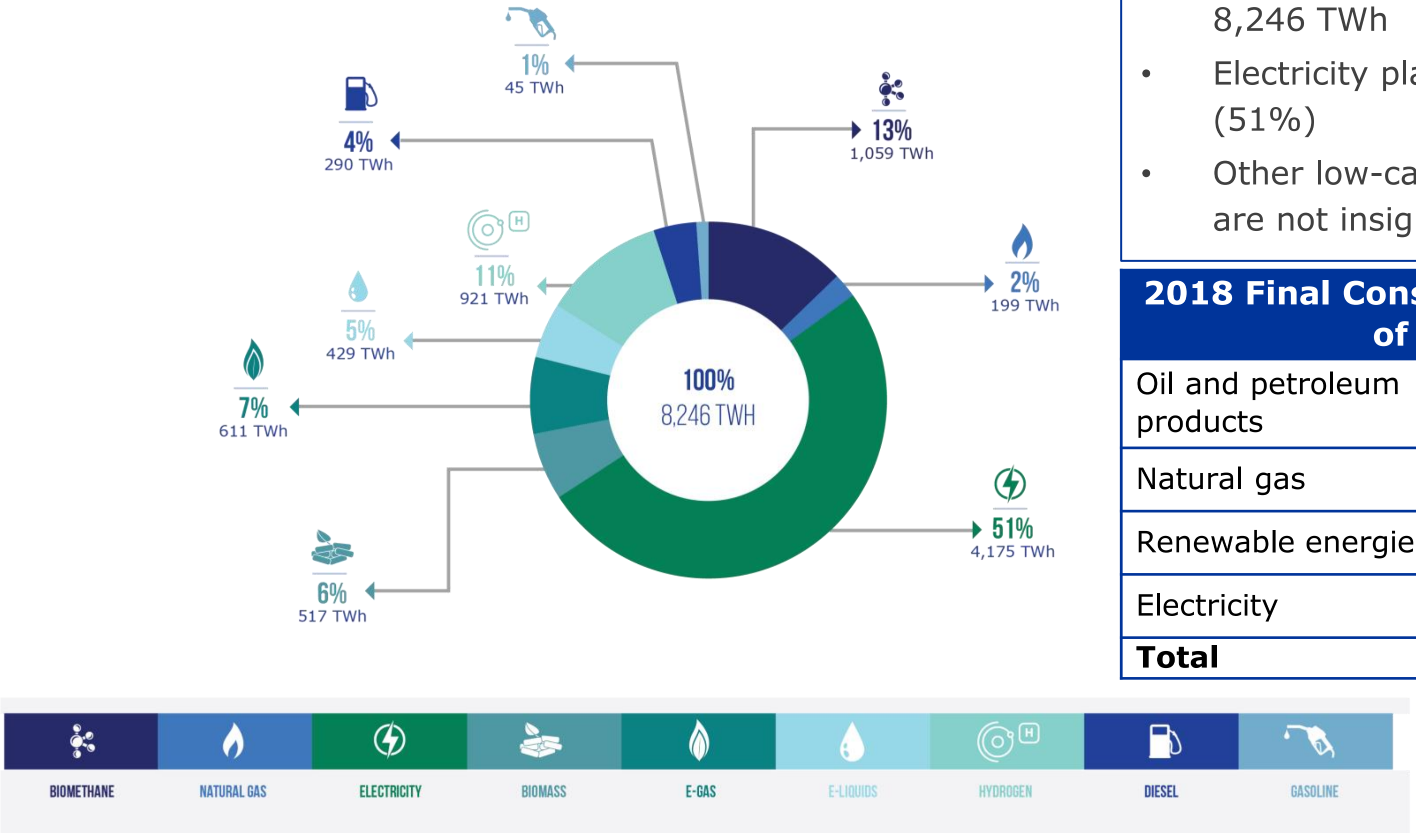
- We consider **sources of flexibility**
  - Networks
  - System integration technologies
  - Storage

STATE-OF-THE-ART
ENERGY SYSTEM OPTIMISATION MODEL



- **Pan-European model:** models DE, IT, NL, BE, FR, UK, IE, PL & the rest is represented as East, Central and South Europe regions;
- It models **existing energy supply,** including **renewables** and **new energy** sources such as **synfuels** (e-gas & e-liquid), H_2, bio-methane;
- **On the demand side,** it includes energy demand in buildings, road transport, industry, and other transport sectors;
- **Model: 92 million** constraints, **73,5 million** variables and **294 million** data points…
- **It covers hourly system operation and investment in infrastructure:**
    - Power generation; heat technologies in buildings; road transport technologies; H_2 production technologies; E-gas & E-liquids;
    - Storage for CH_4, CO_2, H_2, electricity, heat;
    - Transmission and distribution networks and cross border interconnections and trade.

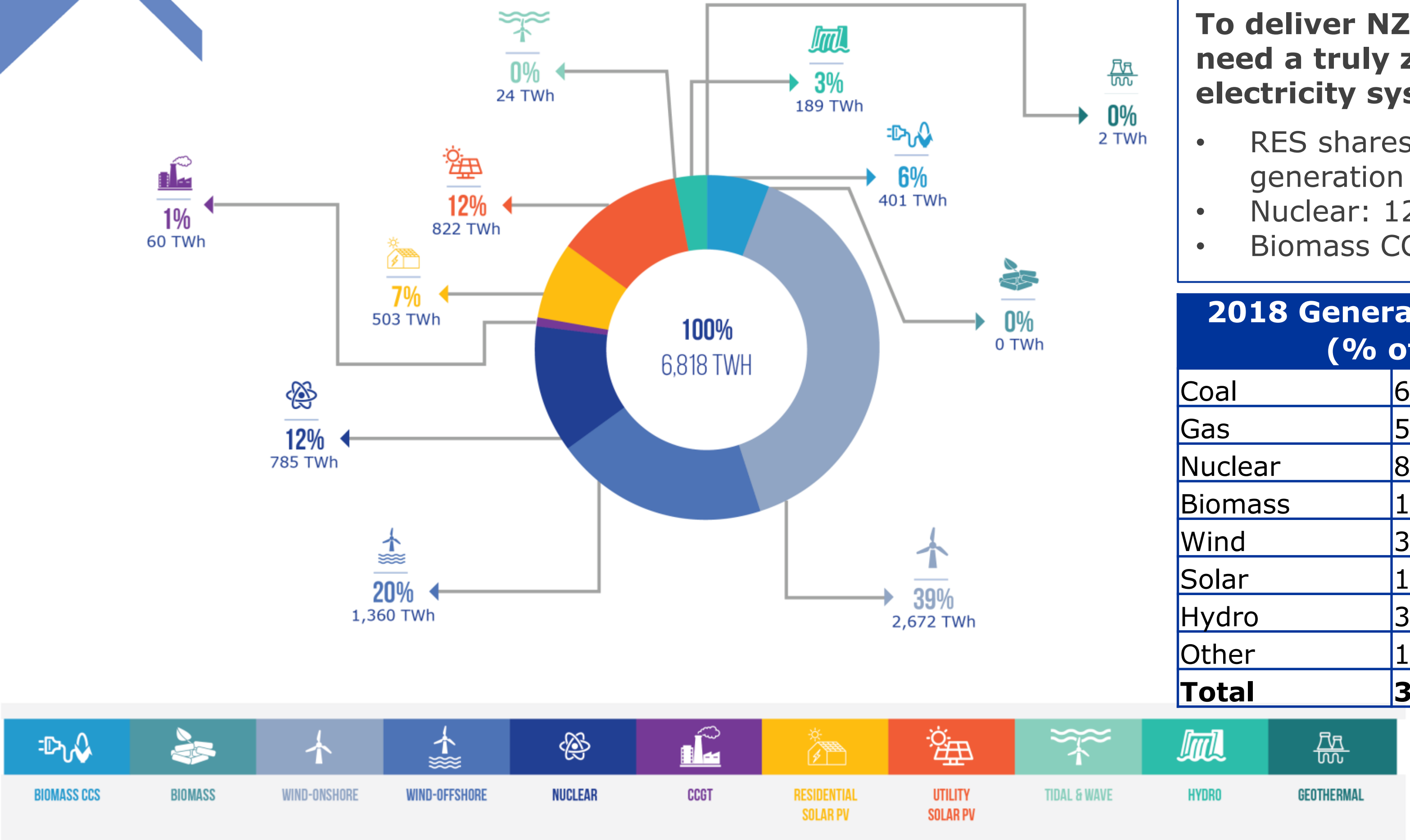
THE ROLE OF ELECTRICITY & LOW-CARBON FUELS IN NZ



- Total final consumption in 2050: 8,246 TWh
- Electricity plays a central role (51%)
- Other low-carbon energy sources are not insignificant (36%)

2018 Final Consumption, TWh (% of total)	
Oil and petroleum products	4,573 (37%)
Natural gas	2,854 (23%)
Renewable energies	1,217 (10%)
Electricity	2,812 (23%)
Total	**12,347(100%)**

THE ROLE OF ELECTRICITY IN NZ – generation mix

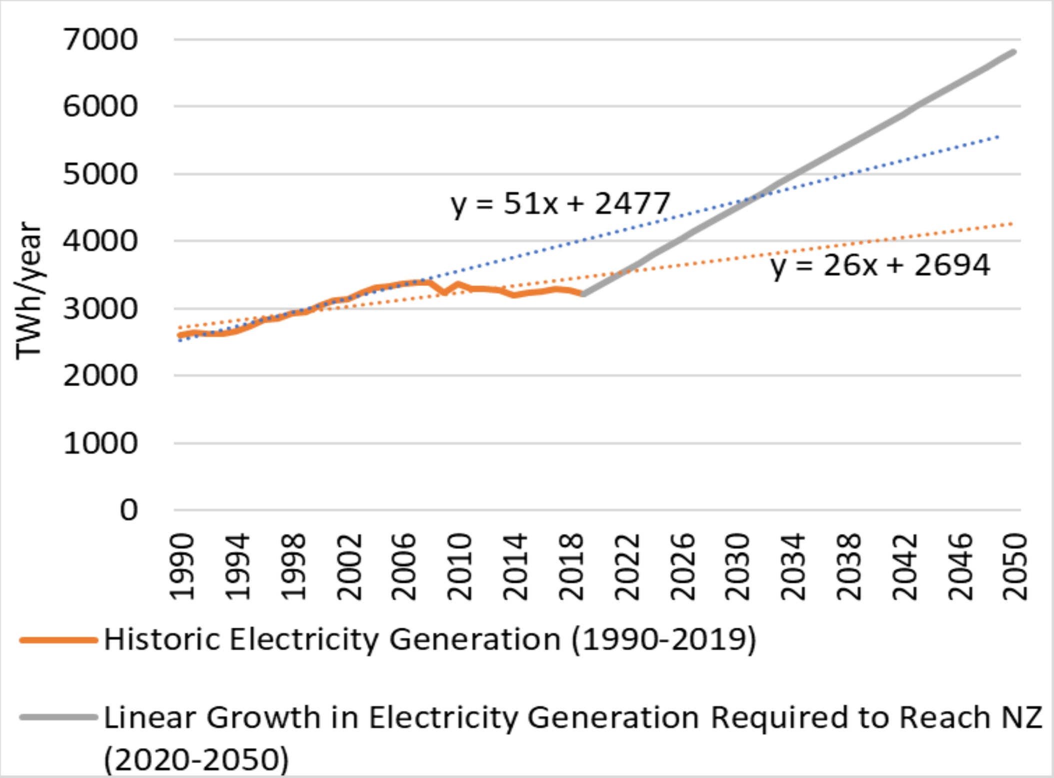


To deliver NZ in 2050, we need a truly zero carbon electricity system!

- RES shares is 81% of total generation
- Nuclear: 12%
- Biomass CCS: 6%

2018 Generation mix, TWh (% of total)	
Coal	621 (20%)
Gas	513 (16%)
Nuclear	860 (27%)
Biomass	100 (3%)
Wind	389 (12%)
Solar	111 (4%)
Hydro	373 (12%)
Other	141 (5%)
Total	**3,135**

THE ROLE OF ELECTRICITY IN NZ – supply expansion



Historic (30 years: 1990-2019) Expansion of Electricity Generation in EU and Required Growth to Meet the NZ Target by 2050

- Electricity supply needs 88% increase relative to 2018 level
- Either *5 times* the historic growth rate in supply (taking 1990-2018 as a whole) or *2 times* the expansion rate before 2008
- Challenging – our NZ requires expansion of certain technologies!

THE ROLE OF ELECTRICITY IN NZ – wind and solar

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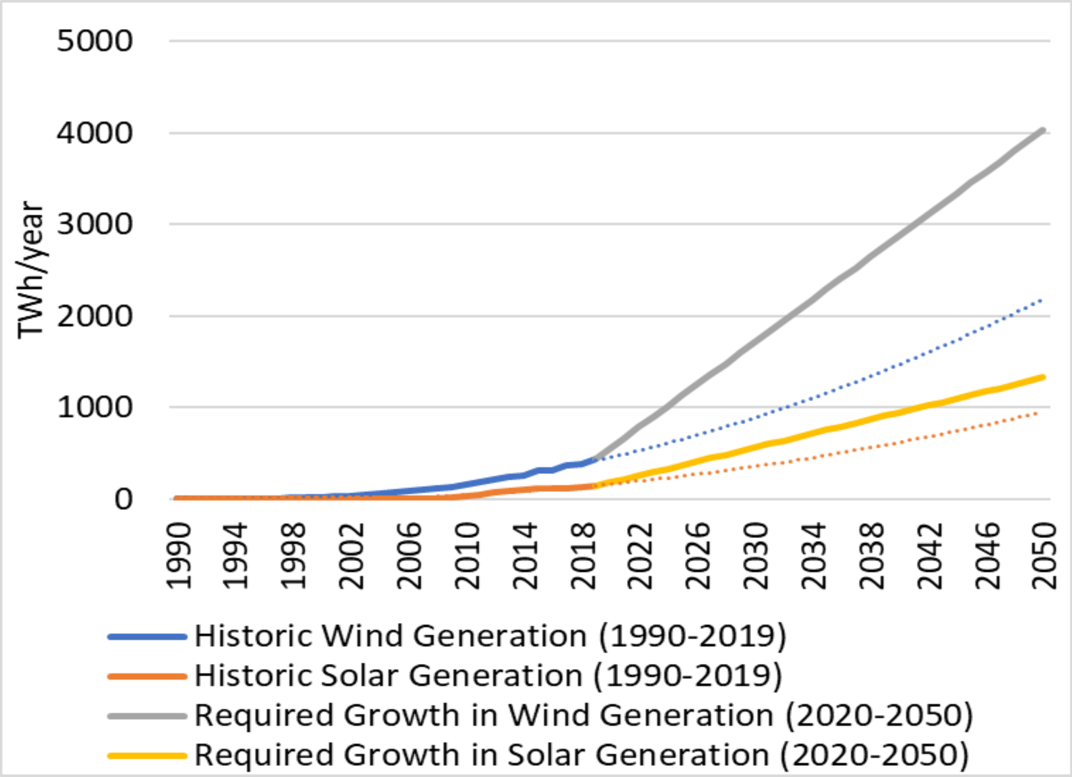
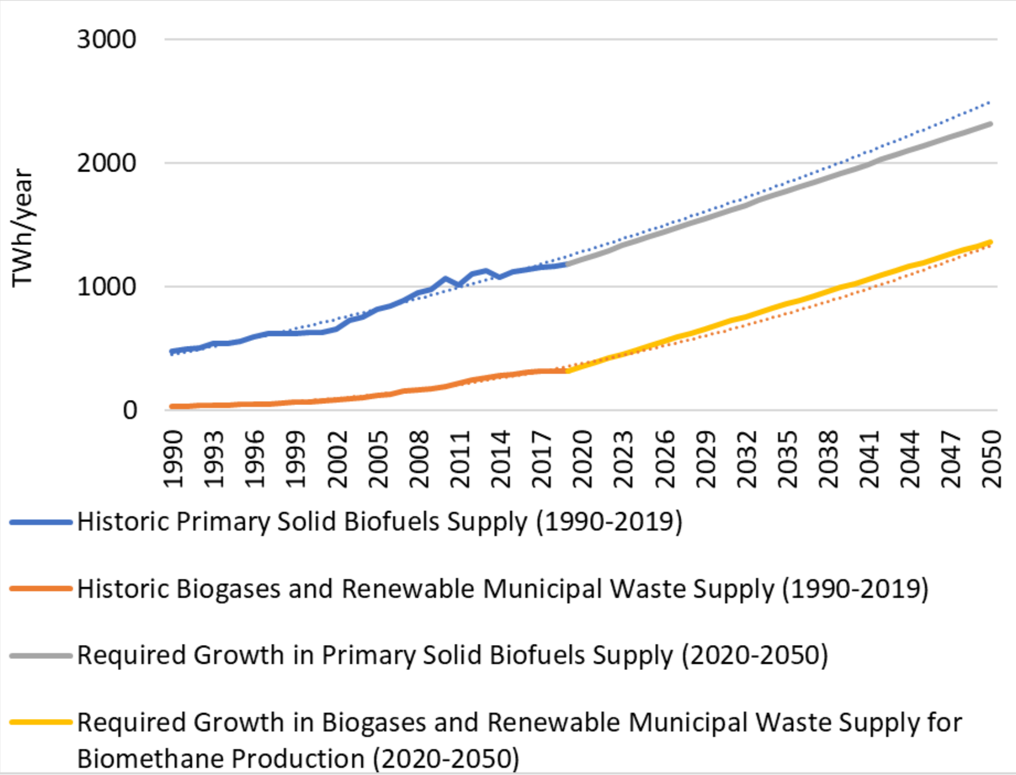


Electricity Generation from Wind and Solar: Historic Trend and the Required Pathways to reach the NZ target by 2050

- Our NZ scenario > 4,000 TWh of wind gen. by 2050
- Double our historic efforts in getting wind onto the energy system.
- Solar generation: based on historic trend we might only miss about 300 TWh of generation

THE ROLE OF BIOENERGY & DERIVATIVES IN NZ

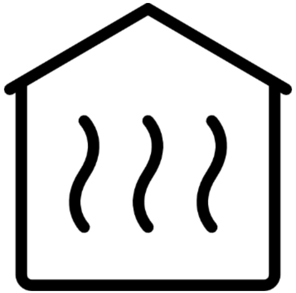


Solid Biofuels and Biogas Supply: Historic Trend and the Required Pathways to reach the NZ target by 2050

- Bioenergy supply requirement in our NZ 2050 does not seem to be a major constraint; BUT two challenges need to be addressed, if we are serious about reaching NZ:

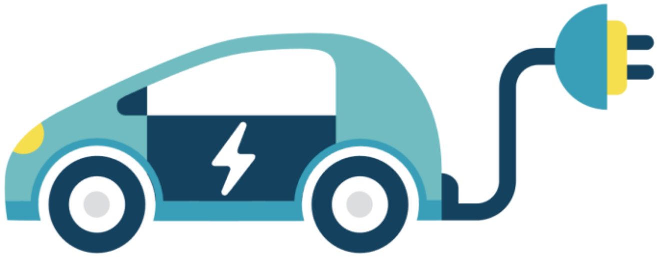
1. **Scaling up of biomethane** production (from biogas) to the required level might be a challenge (in our NZ 2050 biomethane required: 1,150 TWh vs 2018: 23 TWh);
2. **Scaling up of a carbon capture technology** to the required level will be a challenge, given limited success in demonstration of CCS at large-scale so far.

FINAL CONSUMPTION BY SECTORS IN NZ - buildings



- For space and water heating we see uptake of air source heat pump (ASHP) and hybrid heat pump (HHP) with electricity fuel taking 65% of thermal energy services demand
- HHP-gas serves as flexibility and runs at peak hours
- When HHP-gas is running it consumes carbon-neutral bio-methane, e-gas with some fossil gas as well

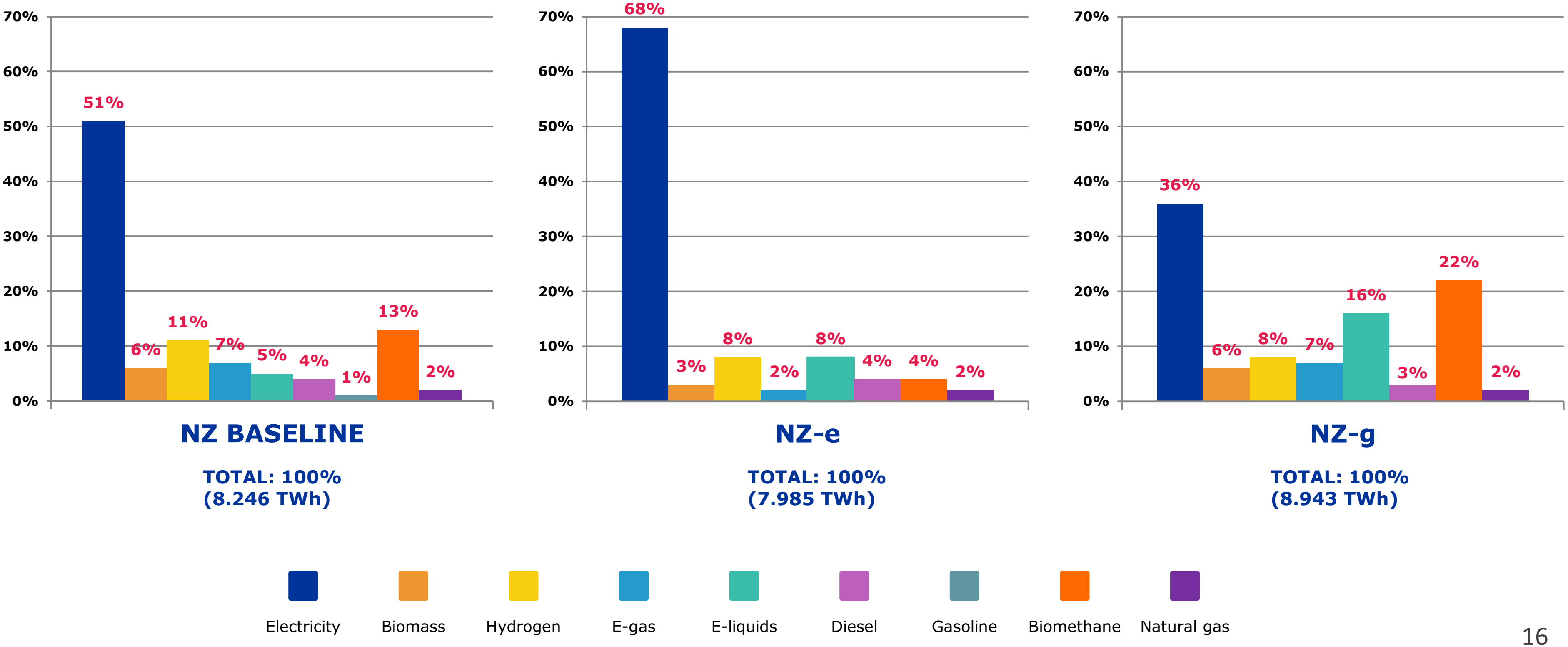
FINAL CONSUMPTION BY SECTORS IN NZ – road transport



- EV Cars constitute 80% of total passenger cars stock
- Diesel cars consumes mostly carbon neutral e-liquids
- Public road transport is mostly electrified (84%)
- HGV is dominated by H2-fueled (64%), gas-mobility (28%) and ca. 8% of the truck fleet is electrified

COMPARISON OF NET ZERO BASELINE VS NZ-E & NZ-G

The role of electricity & low-carbon fuels in final consumption



MAIN FINDINGS OF BASELINE AND ITS VARIATIONS

1. **Central role of electricity** in all 4 scenarios
   - Share of electricity in final consumption could reach 68% in NZ-e…

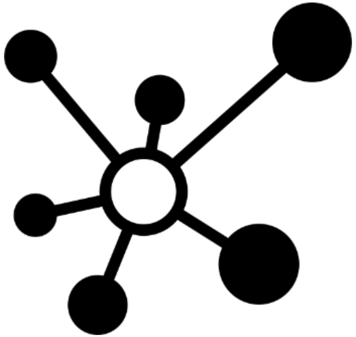
2. **Central role of CCUS as we move from 90% GHG** reduction target to **NZ**
   - removing the residual 10% emissions (i.e., net zero target) requires a four-fold increase in permanent CO_2 sequestration…

3. **Bio-methane supports deep decarbonisation in both 90% and NZ scenarios**, while **H_2 plays a prominent role** when we need to achieve the net zero target

4. **Residual GHG emissions are focused in hard-to-abate sectors** like transport

5. **Power generation sector is largely decarbonised even in 90% GHG** reduction scenario

FLEXIBILITY REQUIREMENTS ARE CRUCIAL



1. Energy system should be **very well connected** to deliver spatial flexibility needed. Investments needed in:
    1. National transmission and distribution grids
    2. Cross-border interconnections to support rapid roll-out of RES from local and remote locations

2. Energy system should **build out all forms of temporal flexibility**:
    1. **Inter-seasonal flexibility**:
        - Traditional seasonal gas (CH_4) storage
        - New forms of seasonal storage – green H_2 production and storage
    2. **Intra-day flexibility**:
        - Hydro-based electrical storage and generation; V2G from EVs and battery storage
        - Pressurized H_2 tanks and liquid H_2 storage
        - Hybrid heat pumps & within day CH_4 pipeline flexibility

RECAPING: KEY OUTCOMES OF THE MODELLING

1. **Key role of electricity** supply sector and electricity-based end-use technologies (e.g., EVs and heat pumps) to deliver NZ…

2. **BUT** the role of bio-methane, hydrogen, synthetic e-fuels and bioenergy with CCUS is also important.

3. All modelling scenarios confirm the need to increase both **traditional and new forms of flexibility** to support deep decarbonisation.

4. **Overall net zero remains an extremely technologically challenging** policy goal, involving multiple new technologies at scale in a 30-year time frame.

5. The failure to scale up any key tech such as RES-E, bio-methane, hydrogen or CCS will block the path to NZ, **necessitating a currently unforeseen technological break-through in the next 30 years.**

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ASSESSING A NEW REGULATORY FRAMEWORK

SESSION 2

STARTING POINT (4 SCENARIOS)
NET ZERO AND 90% RE-MODELLED (LTS, 2018)
2 EXTREME SCENARIOS : **NZ-E & NZ-G**

GENERAL POLICY RECOMMENDATIONS

KEY RESULTS OF THE MODELLING

41 SPECIFIC RECOMMENDATIONS

- Pricing of electricity, gas and carbon (1-6)
- Key role of the electricity system in sector coupling (7-11)
- Organisation of the gas system (12-16)
- Sources of hydrogen and implications of fixed costs (17-18)
- Role of definitions (19-20)
- Initial uses of hydrogen (21-23)
- Financing sector coupling (24-25)
- EU and specific countries (26-29)
- Role of EU in near term (30-34)
- Next steps (35-41)

GENERAL FINDINGS (i)

- **RES-E is essential** and the roll out of wind in particular…
- **A substantial increase of electricity trading** is envisaged
- **Four sets of massively scaled up activities**: hydrogen; its conversion to synthetic methane; synthetic liquid fuel from electricity; use of carbon capture
- **Need to increase bio-methane** and replacement of natural gas with synthetic methane
- **Need to create a separate hydrogen network**
- **Investments in electrolysis, e-liquids and e-gases and CCS**

GENERAL FINDINGS (ii)

- **NZ scenarios vs 90% differ primarily in transport and industry**
- This emphasises the key role of hydrogen and bio-methane in each of our NZ scenarios
- **In our central NZ scenario, the methane network is 50% smaller than today**
- **Fossil fuel prices do continue to make potentially significant differences in our model**. Low methane prices → 'blue' hydrogen. High methane prices + low costs of wind and solar → 'green' hydrogen

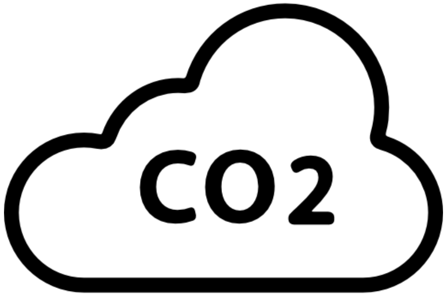
BACKGROUND TO POLICY RECOMMENDATIONS (i)

- The nature of today's energy system has been shaped by the relative availability and price of fossil fuels…
- **The successful scale-up of multiple technologies supported by appropriate policies will be critical…**
- The evolution of the relative costs of wind and solar energy, bio-methane, hydrogen related technology and others remain **subject to the influence of R&D and experimentation and to policy support.**
- Some policy recommendations **must reflect the reality of where we are now** and hence likely to be in the next few years.

BACKGROUND TO POLICY RECOMMENDATIONS (ii)

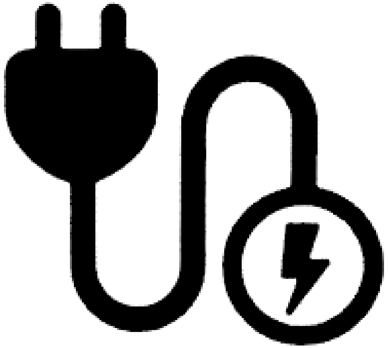
- Massive scaling up of currently nascent technologies – e.g. hydrogen, CCS, bio-methane - are part of our three NZ scenarios
- Our detailed modelling assumes that there are **separate methane and hydrogen networks in 2050**
- We emphasise that we are only modelling net zero in 2050 and not modelling the equally (or indeed more) difficult pathway to net zero

POLICY ON CARBON, ELECTRICITY AND GAS PRICING



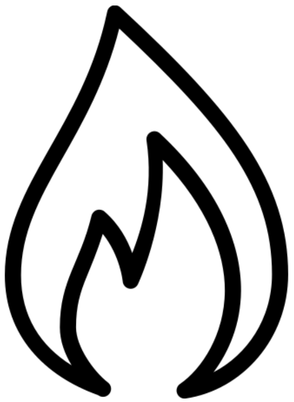
- Harmonisation of taxes/charges
- Question of how the EU ETS should be extended
- Energy efficiency is critical
- Single market in methane needed
- Value of flexibility should reflected
- Huge investment in RES-E still required

KEY ROLE OF ELECTRICITY IN NZ



- Support rapid roll out of **RES-E is critical** to NZ
- **Heavy electrification needs supportive policy** environment towards rapid uptake of electric vehicles
- Electricity transmission and distribution **networks need to be strengthened**
- Substantial increase in the **cross-border trading of electricity**

THE ORGANISATION OF THE GAS SYSTEM

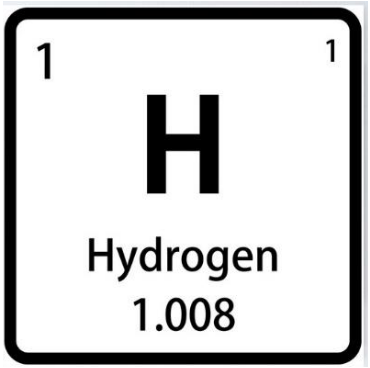


- **Coordination between gas and electricity DSO and TSO**
- Possible joint testing of P2G assets
- Stronger cooperation between gas and electricity system operators
- **Gas network pricing very important**
- Separate methane and hydrogen networks
- Possible alternative sources of hydrogen compete
- **Impact of fixed cost recovery severe**

ROLE OF DEFINITIONS

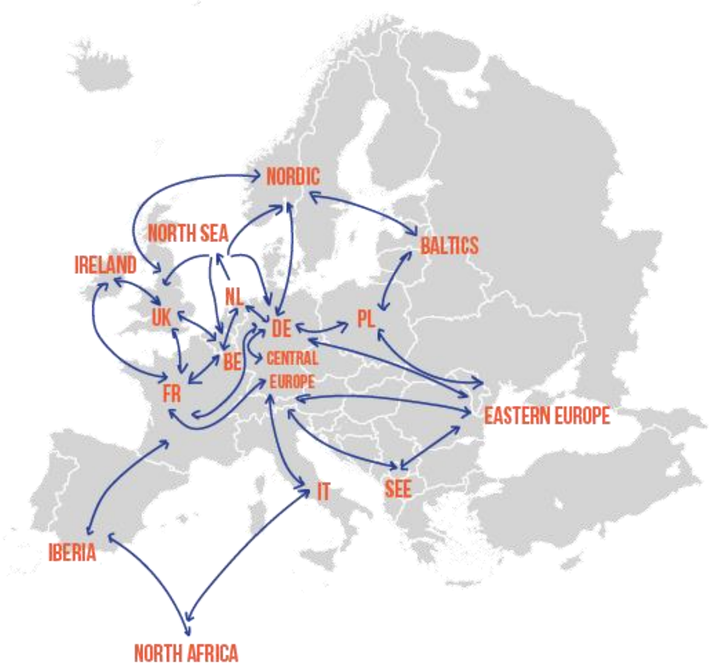
- The definition of green, blue, purple and grey gas is important
- **European Commission to clearly define these** in colourful debate
- Regulation for methane and H2 storage: load or source of supply?

PROMOTING HYDROGEN



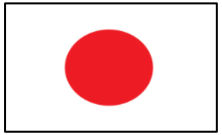
- **Development of a hydrogen network needed**
- In our NZ scenarios:
  - Electricity replaces liquid fossil fuels in light duty transport
  - H2 replaces liquid fossil fuels in heavy duty transport
- Allow electricity and gas distribution and transmission companies to build, own and operate such assets.
- Role of certificates of origin of green gases

DEVELOPMENTS IN SPECIFIC COUNTRIES MATTER



- **A small number of European states are investing in hydrogen**
- Technology emphasis differs
- EU has options to use imports to support decarbonisation
- Watch closely developments in **Australia, Nigeria and Japan**





ROLE OF EU IN NEAR TERM

- **EU plan** on sector coupling is necessary
- Consideration of **RES-G targets** to mirror RES-E
- **Zero carbon transport solutions** important drivers of sector coupling
- Expansion of **cross-border transmission infrastructure in electricity**
- EU needs to be careful **to prevent greenwashing and growth of grey hydrogen**

NEXT STEPS

- **Encourage large scale** innovation projects
- **MS variation in power-to-gas and power-to-H2 policy**
- National TSOs and DSOs in gas **encouraged to participate in** P2G and power-to-H2
- Revision of **Energy Taxation Directive and the EU ETS**
- COVID-19 **recovery package should facilitate NZ**

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ANNEX

DEFINITIONS (i)

- **Blue hydrogen:** hydrogen produced from fossil natural gas with CCS via steam reformation technologies (e.g., steam methane reformation, SMR, and autothermal reforming, ATR, technologies); carbon content of produced H2 is 0; note that production of blue H2 with CCS still emits CO2, depending on assumed capture rate of SMR or ATR;
- **Green hydrogen or power-to-H2:** hydrogen produced from renewable electricity via water electrolysis; carbon content of H2 is 0;
- **E-gas:** synthetic methane produced by combining H2 with CO2 from bioenergy hence carbon neutral;
- **Power-to-gas (PtG):** a group of technologies to produce carbon neutral CH4 (e-gas) using hydrogen and CO2 from biomass generation or biogas upgrading to biomethane;

DEFINITIONS (ii)

- **E-liquids:** synthetic diesel produced by combining H2 with CO2 from bioenergy hence carbon neutral;
- **Power-to-liquid (PtL):** a group of technologies to produce carbon neutral synthetic diesel (e-liquids) using hydrogen and CO2 from biomass generation or biogas upgrading to biomethane;
- **P2X**: refers to either PtG or PtL as understood above;
- **Biomethane or renewable gas:** upgrading of biogas to the specification - 96% CH4 and 3% CO2 - allowing injection into existing gas grids. Biomethane is carbon neutral (i.e., its carbon content is 0), just like biomass for power generation. In the process of upgrading biogas, the CO2 in the biogas is captured and either stored (negative emissions) or used to produce carbon neutral PtG and PtL.

ENERGY SYSTEM MODELLING FRAMEWORK FOR NZ POLICY ANALYSES

- **Primary supply scope:** coal lignite & bituminous, uranium, biomass, natural gas, biomethane, e-gas, H2, Electricity, e-liquids
- **VRE & RES scope:** Hydro, Wind, Solar, Tidal
- **Demand scope:** final energy consumption in (i) buildings (RSD, COM, AGR), (ii) road transport, (iii) industry, (iv) aviation, rail and inland navigation
- **Geographical scope:** EU27+UK+Norway+CH+North Sea&North Africa (14 regions in total)
- **It covers hourly dispatch and investment in capacity**
- **Endogenous choice of key end-use technologies:**
  - Buildings (e.g., space and water heating)
  - Road transport (EVs, FCEVs etc.)
- **Final consumption and GHG emissions calibrated to EC Scenarios for:**
  - Industry
  - Aviation, rail and inland navigation

GHG EMISSIONS BALANCE IN OUR NZ

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TABLE 22
GHG EMISSIONS BALANCE IN THE NZ AND 90% SCENARIOS, MTCO2E

		NET ZERO	90% SCENARIO
[1]	**Stock Change**	**-406,2**	**-100,3**
[1.1]	Underground storage: non neutral emissions	-153.5	-79.6
[1.2]	Underground storage: negative emissions	-252.7	-20.7
[2]	**Transformation**	**612,0**	**457.4**
[2.1]	Gas-fired electricity generation	19.44	21.76
[2.2]	Hydrogen production from natural gas CCS	144.75	83.77
[2.3]	Bioenergy electricity generation	0	15.44
[2.4]	Bioenergy electricity generation CCS	447.84	336.44
[3]	**CO_2 utilization**	**-229,4**	**-276,3**
[3.1]	Synthetic methane production	-121.76	-146.01
[3.2]	Synthetic liquids production	-107.70	-130.30
[4]	**Final Consumption**	**510,9**	**822,1**
[4.1]	Buildings	173.5	171.1
[4.2]	Industry	109.8	175.6
[4.3]	Transport Cars	79.8	76.2
[4.4]	Transport Public	0.0	0.0
[4.5]	Transport HGV	69.3	255.8
[4.6]	Transport Other	78.5	143.5
[5]	**CO_2 neutral emissions**	**-518,0**	**-427,2**
[6]	**LULUCF CO_2 emissions**	**-306,6**	**-240,5**
[7]	**Non CO_2 GHG emissions**	**337,4**	**337,4**
[8]	**TOTAL 2050 (this research)**	**0**	**572,7**
[9]	**TOTAL 2050 (EC LTS)**	**26,1**	**620,1**
[10]	**TOTAL 1990***	**5,408,8**	

Table 22: GHG emissions balance in the NZ and 90% Scenarios, mtCO2e

Our Net Zero baseline results:

Total carbon captured: 636 mn tCO2e; of which:

- From biomass: 447.8 mn tCO2e
- From production of blue H2: 144.7 mn tCO2e
- From direct air capture: 43.5 mn tCO2

Total carbon used: 636 mn tCO2e; of which:

- **Geological storage: 406.2 mn tCO2e (of which negative emissions: 252.7 mn tCO2e)**
- Synthetic fuels: 229.4 mn tCO2

SOURCES OF ENERGY SYSTEM FLEXIBILITY

We conceptualize this into three sources/types:

1. **Spatial flexibility:** moving energy across space to smooth out hourly fluctuations in VRE production in different locations

2. **Seasonal (temporal) flexibility**: moving energy between time periods (summer vs winter) to meet varying energy demand (heat load)

3. **Intraday (temporal) flexibility:** moving energy within a day to smooth out fluctuations in demand and supply in each day

SPACIAL FLEXIBILITY: CROSS-BORDER TRADE IN NZ

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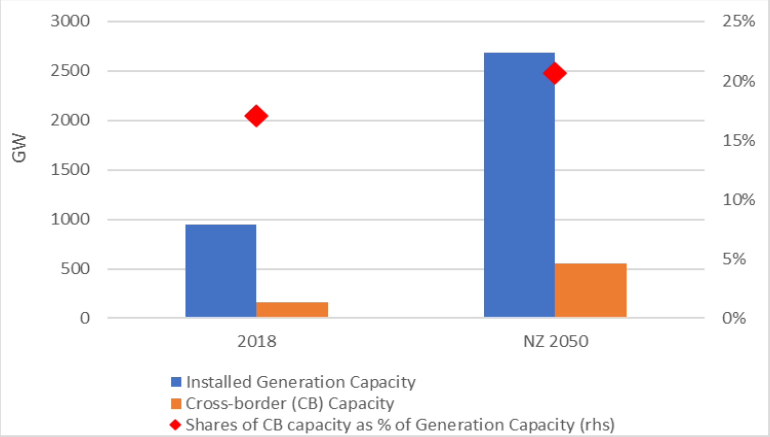
		Imports	Exports	Final Consumption	Shares of Trade in Final Consumption
Electricity	2018	394	366	2784	27%
	NZ 2050	1168	1168	4175	56%
CH4	2018	5016	954	5327	112%
	NZ 2050	1190	283	1869	79%
Hydrogen	NZ2050	25	25	921	5%

Electricity, CH_4 and H_2 cross-border trade: 2018 vs NZ 2050



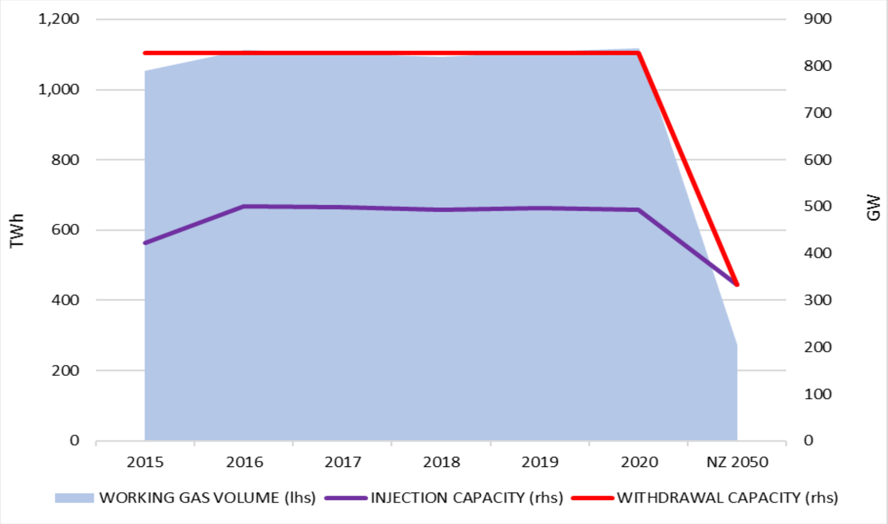
Electricity Cross-border Interconnection and Generation Capacity for EU+UK: 2018 vs NZ 2050

- As the role of electricity becomes central, so is cross border trade: total **trade in electricity increases** by a **factor of 3** (relative to 2018)
- the proportion of such capacity is quite in line with 2018. The **share of cross-border capacity** in total installed generation increases from **17% (2018) to 21% in NZ 2050**
- We can see that the **total trade in CH4 reduces by a factor of 4**
- role of **cross-border in H2** might be **limited** in our NZ 2050

TEMPORAL FLEXIBILITY REQUIREMENTS IN NZ – seasonal storage

	Electricity	H_2	CH_4
Volume, GWh	461	8,306	272,735
Power, GW	99	671	334
Average storage system duration, hours	5	12	816

Electricity, CH_4 and H_2 Storage Capacity in NZ 2050



Evolution of EU+UK Gas Storage from 2015 to NZ 2050

- **Inter-seasonal flexibility** in the NZ scenario is provided by **CH4** long-duration **storage** (traditional underground gas storage)
- With the **reduced requirement for CH4** in the **buildings** sector (predominantly for heat load) **less** inter-seasonal **storage capacity** will be **required in NZ 2050**
- **CH4 storage volume** needed to move energy from summer to winter season will **reduced by a factor of 4** (from the existing storage volume of 1,117 TWh to 272.7 TWh in NZ 2050)

TEMPORAL FLEXIBILITY REQUIREMENTS IN NZ – intraday flexibility

When it comes to **intraday flexibility** in our NZ energy system, it is delivered by a combination of:

1. **electrical energy storage**: both traditional storage solutions like **hydro-based** electrical storage and generation, as well as new forms of intraday flexibility – **V2G** from EVs and electrical energy **battery storage**

2. from H2-based intraday storage solutions, like **pressurised H2 tanks** and **liquid H2 storage** technologies

3. And, **hybrid heat pumps** which allow for greater system flexibility associated with within day ramping requirements to meet heat loads

While there are 99 GW of hydro pumped and electrical energy storage systems, intraday electricity flexibility could be provided by some EVs:

1. In NZ there are **268 million EVs**, of which 75%, are private passenger cars

2. we see **120 GWh of peak V2G** output from passenger EVs, or 1.4% of total EV battery capacity

THE DIFFERENCE NZ MAKES

We actually model 3 other scenarios, one of which is a 90% emissions reduction Scenario, also in the EU modelling. This illustrates the effect of pushing on to NZ.

	NZ SCENARIO		90% SCENARIO	
	FINAL CONSUMPTION	SHARES IN TOTAL	FINAL CONSUMPTION	SHARES IN TOTAL
Biomethane	1,059	13%	1,040	12%
E-gas	611	7%	647	8%
Electricity	4,175	51%	4,093	49%
Hydrogen	921	11%	210	3%
Natural gas	199	2%	323	4%
Gasoline	45	1%	305	4%
Diesel	290	4%	661	8%
Biomass	517	6%	508	6%
E-liquids	429	5%	582	7%
Total	**8,246**	**100%**	**8,369**	**100%**

Table 18: Final Energy Consumption (TWh) in NZ and 90% Scenario

EMISSIONS DIFFERENCES IN NZ

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TABLE 22

GHG EMISSIONS BALANCE IN THE NZ AND 90% SCENARIOS, MTCO2E

		NET ZERO	90% SCENARIO
[1]	**Stock Change**	**-406,2**	**-100,3**
[1.1]	Underground storage: non neutral emissions	-153.5	-79.6
[1.2]	Underground storage: negative emissions	-252.7	-20.7
[2]	**Transformation**	**612,0**	**457,4**
[2.1]	Gas-fired electricity generation	19.44	21.76
[2.2]	Hydrogen production from natural gas CCS	144.75	83.77
[2.3]	Bioenergy electricity generation	0	15.44
[2.4]	Bioenergy electricity generation CCS	447.84	336.44
[3]	**CO_2 utilization**	**-229,4**	**-276,3**
[3.1]	Synthetic methane production	-121.76	-146.01
[3.2]	Synthetic liquids production	-107.70	-130.30
[4]	**Final Consumption**	**510,9**	**822,1**
[4.1]	Buildings	173.5	171.1
[4.2]	Industry	109.8	175.6
[4.3]	Transport Cars	79.8	76.2
[4.4]	Transport Public	0.0	0.0
[4.5]	Transport HGV	69.3	255.8
[4.6]	Transport Other	78.5	143.5
[5]	**CO_2 neutral emissions**	**-518,0**	**-427,2**
[6]	**LULUCF CO_2 emissions**	**-306,6**	**-240,5**
[7]	**Non CO_2 GHG emissions**	**337,4**	**337,4**
[8]	**TOTAL 2050 (this research)**	**0**	**572,7**
[9]	**TOTAL 2050 (EC LTS)**	**26,1**	**620,1**
[10]	**TOTAL 1990***	**5,408,8**	

Table 22: GHG emissions balance in the NZ and 90% Scenarios, mtCO2e

Notes: [8]=[1]+[2]+[3]+[4]+[5]+[6]+[7]; * Total CO2e, including indirect CO2,

with land use, land-use change and forestry; Stock Change means CO2 storage;

CO2 neutral emissions are emissions from combustion of bioenergy; non CO2

GHG emissions are primarily methane, nitrous oxide and fluorinated gases.

ELECTRICITY UNDER DIFFERENT ASSUMPTIONS

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We then flex NZ scenario to give two new extreme scenarios (NZ-e, NZ-g) essentially doubling or halving cost assumptions in order to favour gas or electricity, e.g. cheaper wind vs cheaper methane.

	NZ SCENARIO		NZ-E SCENARIO		NZ-G SCENARIO	
	GENERATION	SHARES IN TOTAL	GENERATION	SHARES IN TOTAL	GENERATION	SHARES IN TOTAL
CCGT	60	1%	0	0%	231	6%
Hydro	189	3%	94	1%	274	7%
Nuclear	785	12%	763	9%	806	19%
Residential Solar PV	503	7%	523	6%	503	12%
Biomass	0	0%	0	0%	265	6%
Biomass CCS	401	6%	367	4%	754	18%
Tidal & Wave	24	0%	0	0%	36	1%
Utility Solar PV	822	12%	281	3%	251	6%
Wind Offshore	1,360	20%	2,180	26%	639	15%
Wind Onshore	2,672	39%	4,100	49%	413	10%
Geothermal	2	0%	1	0%	3	0%
Total	**6,818**	**100%**	**8,309**	**100%**	**4,176**	**100%**

Table 25: Electricity Generation (TWh) Mix in the NZ Scenario and its Variants (NZ-e and NZ-g)

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Centre on Regulation in Europe

Improving network and digital industries regulation

Avenue Louise, 475 (box 10)
1050 Brussels, Belgium

cerre.eu
@CERRE_ThinkTank
info@cerre.eu

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