ENGSCI 700A/B

ENGSCI 700 Research

Connor McDowall
cmcd398
530913386

April 27, 2020

Listings

Contents

List of Figures

List of Tables

1 Journal Log and Supervisor Meetings

1.1 Meeting 1: 19/03/18 in Person

Discussion Points

- COVID-19: Planning to move University and Project Online
- COVID-19: Impact on Share Prices
- Eyal Ofer and Stock Market Volitility
- Commtrade.co.nz and NZ Carbon Price Spot Market

Action Points

- Waka and Kayak Energy Scenarios
- Emissions Trading Scheme
- Economic Model underpinning the Scenarios

1.2 Meeting 2: 25/03/18 via Zoom

Discussion Points

- Relocation around the Country
- Outline of existing research document
- Discussed meeting

Action Points

- Continue with Research Document
- Looks at wider socio-economic factors
- Understand TIME and MARKAL Model
- John Carnegie is now head of PEPANZ. Rosalind mentioned getting coffee with him when COVID-19 lockdown finishes.

1.3 Meeting 3: 9/04/18 via Zoom

Discussion Points

- Meeting postponed

Action Points

- Insert

1.4 Meeting 4: 16/04/18 via Zoom

Discussion Points

- COVID-19 Response from Auckland and Victoria

- Research resources
- Discussion on getting GAMS on FlexIT

Action Points

- Continue research document and drafting literature review
- Test FlexIT System when access granted

1.5 Meeting 5: 23/04/20 via Zoom

Progress Report (16/04/20 - 23/04/20)

- Drafted two of five pages for literature review
- Reviewed twelve academic papers/journals/reports for Literature Review

Discussion Points

- Oil Market Activity including WTI Negative Oil Prices
- Rosalind's experience at Stanford (Alumni Commitments, PHD, Computer Science Course)
- Installing a VM in install GAMS
- Quality of Literature and Reliable Sources

Action Points

- Continue research document and drafting literature review to submit to Rosalind on 27th of April
- Test FlexIT System when access granted

1.6 Meeting 6: 30/04/20 via Zoom

Progress Report (23/04/20 - 30/04/20)

- Drafted eight of 10 pages for literature review
- Reviewed 26 academic papers/journals/reports for Literature Review
-

Discussion Points

-

Action Points

-

2 New Zealand Energy Scenarios

- The report informs how to leverage New Zealand's competitive advantage with abundant natural resources, ease of business, strong export sector and high standards of to inform how we sustainably grow business while addressing the issues in the global energy sector.

- Predicting the future becomes harder with technological development, requirements for quicker policy changes, and investment decisions.
- The BusinessNZ Energy Council has developed a report outlining two different future energy scenarios for New Zealand (Kayak and Waka)
- 19 critical uncertainties underpin these two scenarios. These varied from external sources such as **global stability**, domestic economy factors such as **International Fuel Markets, urban sustainability, energy affordability , and the allocation of natural resources**
- The world energy council (WEC) is the principal impartial network of energy leaders (3000 member organisations in 100 Counntries) to plan these scernarios.
- The scenarios enable businesses and policy makers to make decisions to inform their future strategy and operations.
- The scenarios are to: develop a platform for ongoing projects and researching energy options for New Zealand's future create a positive policy and investment climate that promotes new technology and innovation, as well as supporting energy sector developments.

2.1 Kayak Scenario

- The markets drive supply chain decisions and innovation more than the government. Consumers and Producers will make decisions in their best interests based on price and quantity. Market forces drvei the decisions. The government focuses on establishing strong competitive frameworks relying on the pursuit of least cost energy supply. International commitments to reducing emissions are weak.
- The government relies on net immigration and the public perception of New Zealand being being clean and green.
- Heightened environmental awareness will drive businesses and consumers to rely on GOVT to make decisions in national interest. Markets and technology deliver more affordable energy over time with a greater focus on energy equity. There will be no support for low-carbon technologies apart from a modest carbon price.
- Key statistics in 2050:6.15m population, 503B GDP, \$ 60 / Tonne. 30 Mt/pa of Carbon Emissions. 85% of electricity generated from renewable resources. Greater focus on energy equity over security and sustainability. No change in energy intensity per annum.

2.2 Waka Scenario

- Business and Consumers reply on Government to make decisions from a nationalist perspective to meet environmental sustainability goals.
- Reducing global carbon emissions will be at the expense of economic growth. Exports will be be hurt by rising global carbon prices. New Zealand loses it's compet-

itive advantage with a sustainable green image.

- New Zealand focuses on disrupting traditional methods of transport and adopting 100% renewables for electricity generation (Confirm if Retail and/or Industrial Demand).
- Energy sustainability is prioritised over security (inherent in non renewable resources) and equity.

2.3 Kayak and Waka Comparison and Analysis of Scenarios

Both are two extremes on the spectrum. Combinations of scenarios exist as Kayak and Waka exist at opposite ends of the scenario spectrum. The progression towards sustainable energy outcomes is unrealistic without a concensus from both consumers, businesses, and Government. Consumers and producers will mostly choose Kayak as mostly aligns with their commercial priorities. Trusting market forces in this context won't lead to change. The factors in table 1 may inform which metrics are best suited to refine a global carbon pricing model.

2050 Factor	Waka	Kayak	Comment
Population (m)	5.55	6.15	Lower immigration for Waka
GDP ($B (NZD))	416	503	Net exports hurt from higher costs
Carbon Price ($/T)	115	60	No comment
Carbon Emissions (Mt/pa)	18	31	No comment
Renewable Energy Generation (%)	98	85	No comment
Carbon Intensity	0.05	0.07	kg CO_2 per $ GDP
Energy Intensity	-2.0	-1.7	Δ% p.a.
Energy Self-Sufficiency (%)	88	94	Rely on Imported Power
Investment (NZD $B)	14.4	15.4	(Electricity Generation)
Total Energy Consumption (PJ/p.a)	520	680	No comment
Alternative Light Vehicles (m)	3.3	1	Alterative Light Vehicles
Alternative Light Vehicles (m)	0.5	3.3	Internal Combustion Engine

Table 1: Key Statistics: New Zealand Energy Scenarios

All information relating to the New Zealand Energy Scenarios 2050 is cited from [2]

3 New Zealand Energy Scenarios - Navigating our Flight Path to 2060: Kea and Tui

3.1 Introduction

- Worked with Public and Private Sector Investors, and the Paul Scherrer Institute from Switzerland.
- Reworked the Kayak and Waka Scenarios into Tui and Kea

- New Zealand faces rapidly changing energy use, blurring boundaries between previously isolated elements, emerging disruptive technologies, and the challenge of sustainable living.
- Tui and Kea inform modelling insights

3.2 Tui and Kea

- Declining technology costs have contributed to the change and sentiment surrounding the responce to the main challenges and opportunities.
- The relationship between relying on the government action or the public markets.
- Carbon prices are a modelling input to the New Zealand Energy Reports.

3.2.1 Tui

- Global Community Effort
- New Zealand does not generally have a common view on what is important.
- Adopts a wait and see approach with some protection provided to local businesses.
- New Zealand focuses firstly on Economic Prosperity and Individually Wellbeing by leveraging off comparative advantages. Purely commercial Reponses.

3.2.2 Kea

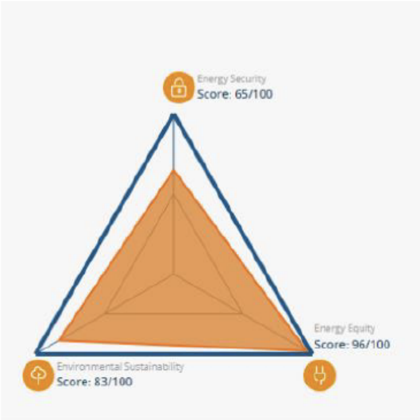
- Economy cannot remain internationally competitive with current emissions intensity.
- New Zealand takes leadership (International and Domestic) in lowering emissions, choosing to undergo an early and agressive economic transformation
- NZ acts before the global economy.
- Most likely to hurt the economy.

3.3 BEC2060 Key Messsages

- A changing society and economy. Service Industries will have a greater empathesis with less reliance on primary produce.
- Renewables will help decarbonisation, convert much of industrial and transport fleet heat to energy. Don't neglect hydrogen and biofuel opportunity tougher industries to de carbonise (aviation, marine) and also consider energy efficiency.
- Secure energy in weather volatility.
- Consider diversifying investment in new technology
- Consider a diversified carbon neutralisation plan to balance reductions with economy performance.
- Consider the inteconnectivity of industries when considering siloed risk.

- New Zealand is raned 10th of the World Energy Council's Trilemma.
- Three factors influence the rating: Energy Security, Energy Equity, Environmental Sustainability Risk.
- New Zealand Performance in 2060 under the two scenarios is shown below.

New Zealand's Energy Trilemma Performance in 2060

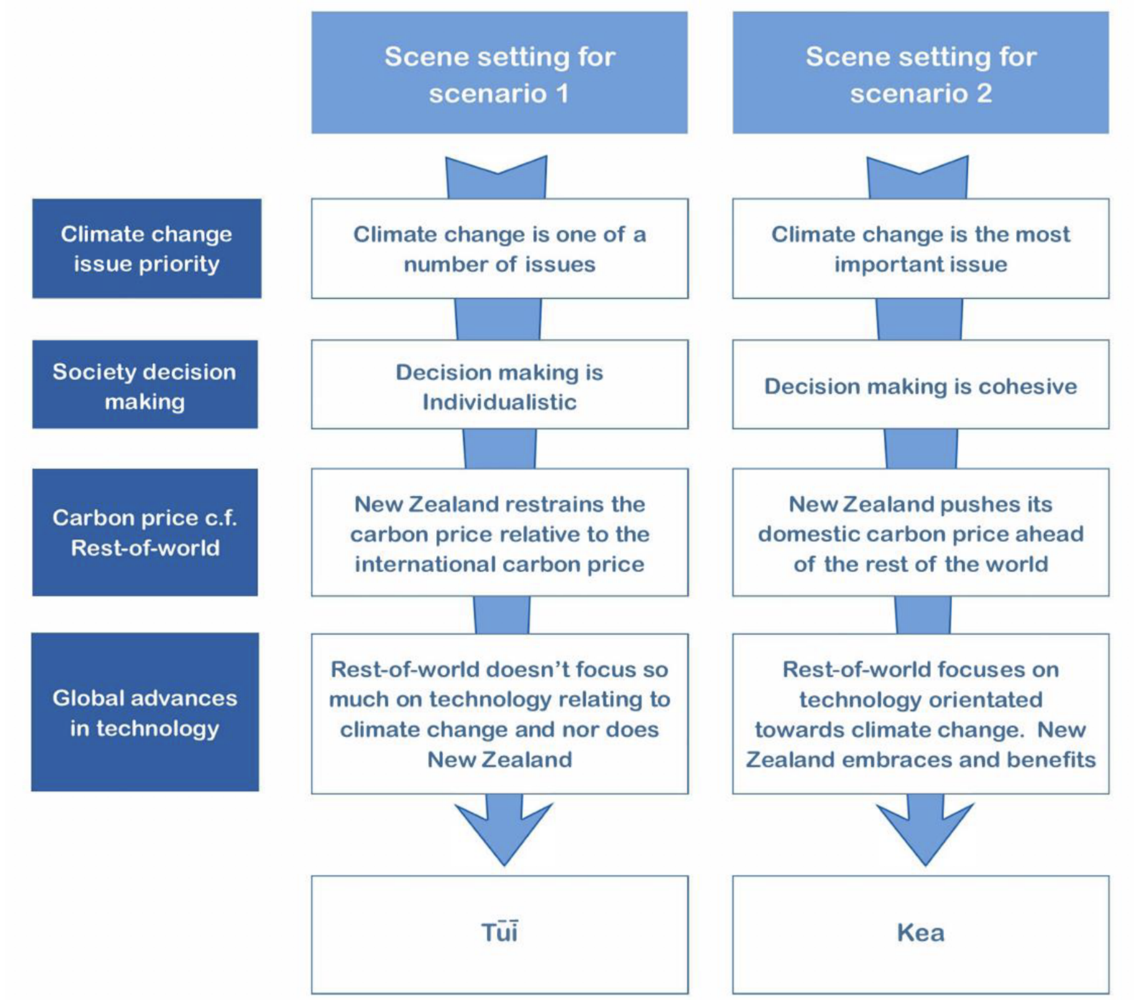
Kea 2060	**Tūī 2060**
	
Energy Security - Lower diversity of energy supply - Energy self-sufficiency 92% - Lower import dependence: - Net imports primary energy supply 10% - Oil product net import 100PJ - LNG net import 0PJ - Coal net import 0PJ - Domestic gas production 35PJ	**Energy Security** - Higher diversity of energy supply - Energy self-sufficiency 87% - Higher import dependence: - Net imports primary energy supply 14% - Oil product net import 170PJ - LNG net import 54PJ - Coal net import 0PJ - Domestic gas production 0PJ
Energy Equity - GDP per capita 152,757$/person - Carbon price $205/t - Electricity price $100/MWh - Diesel and Petrol price $37.42/GJ - Natural gas price $9.45/GJ - Total energy consumption 600PJ - Energy savings through energy efficiency 800PJ	**Energy Equity** - GDP per capita 122,749$/person - Carbon price $130/t - Electricity price $220/MWh - Diesel and petrol price $32.15/GJ - Natural gas price $20.98/GJ - Total energy consumption 720PJ - Energy savings through energy efficiency 600PJ
Environmental Sustainability - Energy intensity 0.6MJ/$GDP - Energy sector carbon emission 10Mt/pa - Energy carbon emission intensity 0.01kg/$GDP - Renewables in energy 88% - Renewables in electricity 95% - Electrification 50%	**Environmental Sustainability** - Energy intensity 0.9MJ/$GDP - Energy sector carbon emission 17Mt/pa - Energy carbon emission intensity 0.02kg/$GDP - Renewables in energy 83% - Renewables in electricity 90% - Electrification 50%

1. Analysis of Kayak and Waka
2. Investigate proliferation of Scenarios

3. Explorative: Generally explicit about societal and political elements. A strong focus on robust input assumptions guiding modelling instead of outcomes.
4. Focus on techno-economic elements. These are evidence based predictions that aim to establish a base case then look at incremental costs and benefits of policies (Conditional Scenarios).
5. Normative Scenarios: Output driven (UNFCCC or UNSDG Agenda). Backcast to create planning roadmaps.
6. Explore different scenarios to avoid anchoring bias.
7. The scenarios help explore New Zealand's Energy Interconnectivity with the rest of the world.
8. Scenarios allow for more complex growth analysis.
9. Consider energy demand from Emerging Technologies.
10. **Forecast energy demand, technology uptake, to look at relative supply. Cool use of ML possibly**
11. The inflection point is 2040 to deem if the report is successful or not.

There are four critical uncertainties underpinning scenarios due to the number of possible permutations.

1. The way New Zealand - as a society - makes decisions in the future, being either more cohesive or individualistic.
2. Domestic Acceptance of Climate Change as climate change one of or the most important issue to address.
3. The level or actual price of carbon compared to the rest of the world.
4. The degree technology is available to address energy balance and emissions domestically.



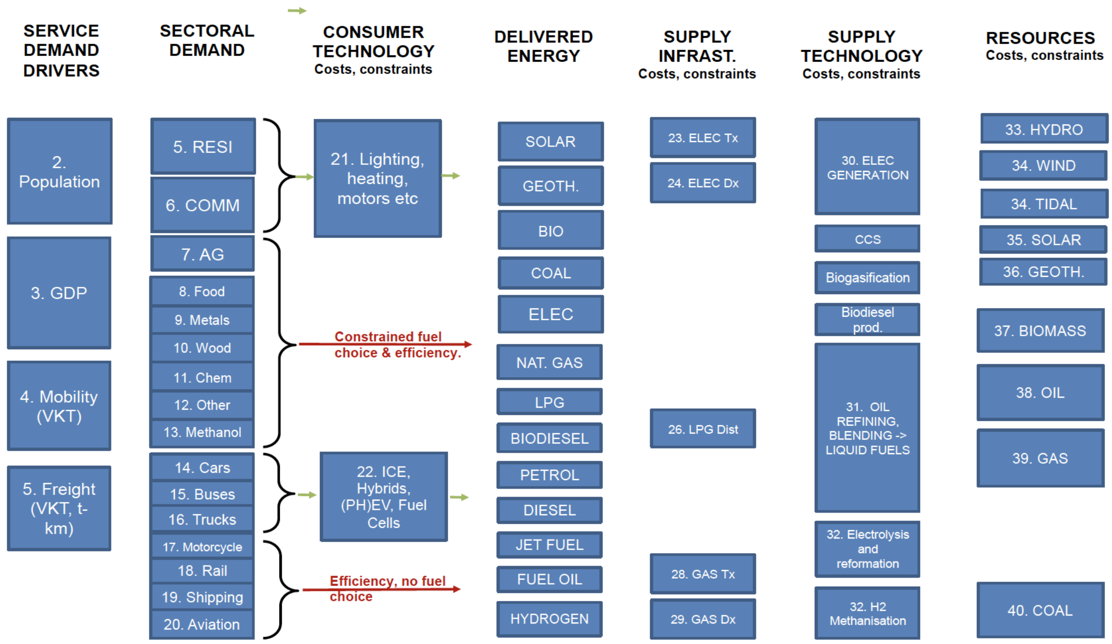
All information relating to the New Zealand Energy Scenarios 2050 is cited from [3]

3.4 TIMES Model

Modelling the Energy Scenarios Relies on the TIMES Model, an integrated energy-systems model.

- A linear optimisation model, minimising total discounted costs, through time, of meeting all energy service demand.
- Simultaneously models all components of an energy system.
- Services demanded of the energy system as inputs, not simply forecasts of energy demand. Eg. Vehicles kms travelled or space required for heating.
- The model determines which are the optimal technologies to use for the project.
- You must forecast services demand.
- An array of economic information is produced as a part of the solution, imforming implied commodity prices
- The model has the limitations of a linear model. Maximising the use of a particular technology even if it is only fractionally better than another.

Figure 3 - The Structure of TIMES-NZ



The rest of the report details the impacts both Tui and Kea have on all the relavant economic indicators. All information in this section was gathered from

4 World Energy Scenarios 2019 - Full Report

4.1 Key Facts and Summary

5 TIMES Model

5.1 Key Facts and Summary

- TIMES Model now underpins energy planning around Climate Change and Greenhouse Gas Emissions.
- TIMES Model is a bottom up model.
- The model can represent an entire economies energy supply chain with Demand, Process and Supply all modelled.
- The TIMES model objective is the satisfaction of an exogenous energy service demand at a minimum of total cost over the entire planning horizon.
- The model determines the optimal use of fuels and technologies at each period, and the associated trading and emissions activities.

5.2 Generalization of the Model

$$NPV = \sum_{r=1}^{R} \sum_{y=YEARS} (1 + d_{r,y})^{REFYR-y} \times ANNCOST(r, y) \tag{1}$$

Where:

- NPV = Net Present Value of the Total Costs
- ANNCOST = Total Annual Cost
- d = General Discount Rate
- r = Region
- y = Years for which their are costs
- REFYR = Reference year for Discounting
- YEARS = Set of years there are costs

TIMES PT uses a partial equilibrium version of TIMES. The actual system encompasses all the steps from primary resources in place to the supply of the energy demanded from consumers through all the relevant processes. See another example of the TIMES structure below.

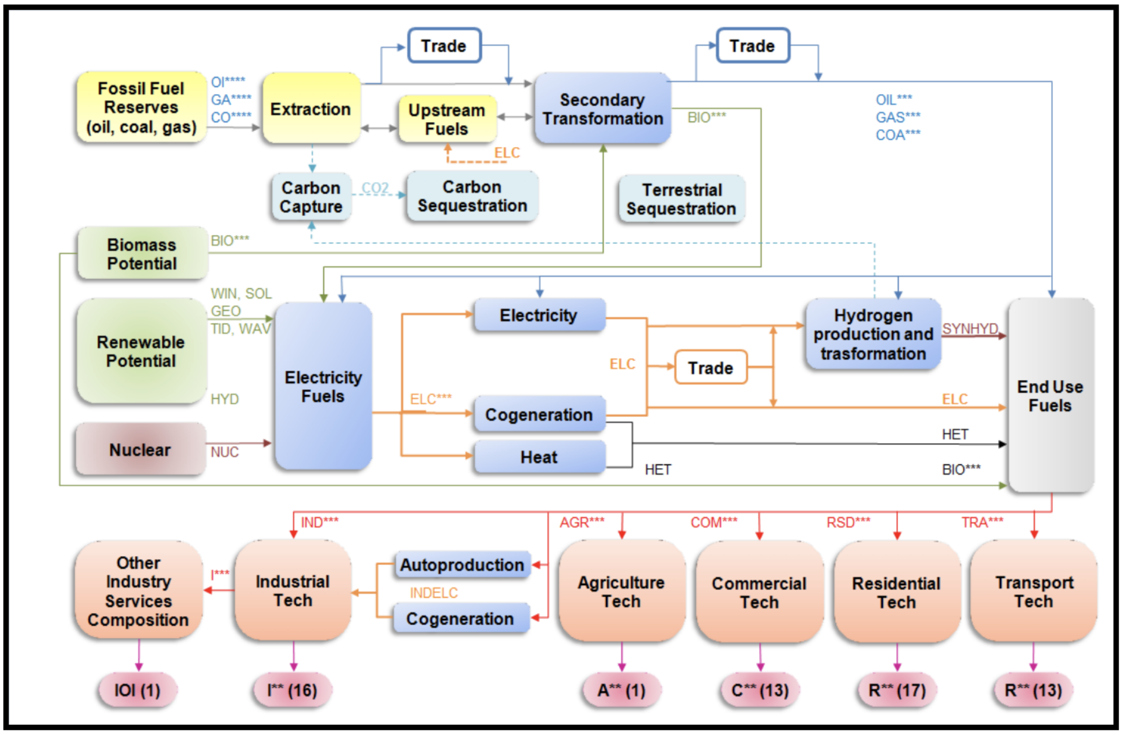


Fig. 1. High-level Reference Energy System of a single region model [5].

- Each item characterised by several input parameters of existing and future technologies. They are described by means of technical data (capacity,fficiency), environmental emission co-efficients (CO2 etc), and economic values (capital cost, date of commercialisation). Reference demands for energy services and supply curves of the resources help drive drive future developments.

- The model is sliced into different sectors: Primary Supply covering Resource Origination, extraction, importing, processing, transport, and distribution. each primary resource is modelled independantly, and represented by a linearised stepwise supply function. the number of steps approximating each curve depends on the resource and on the country reserves. The energy commodities are disaggregated to the level of detail of the extended national energy balances.

- Demand sectors are also represented: In this article, there are 5. 1). Agriculture, 2). Industry, 3). Services, 4). Residential, 5). Transport.
- Energy services demand is fed into the model.
- Renewable Energy Potential, Primary Energy Prices, Technology Costs and Characteristics. The model combines the technical economic data with energy pricesto dynamically calculate supply cost curves.
- There are TIMES technology databases which help forecast trends in technology for the model.
- The model can be used for several applications of GHG, air pollutant, and energy scenarios.

All information in this section was cited from [4]

6 MARKAL Model

6.1 Key Facts and Summary

7 McKinsey & Company: The Future is Now: How Oil and Gas Companies can Decarbonise

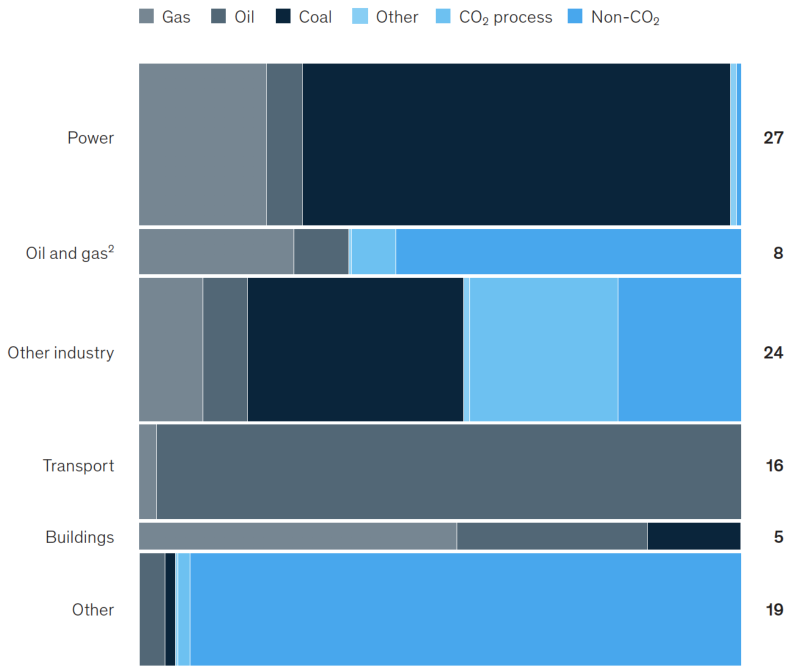
7.1 Summary and Key Facts

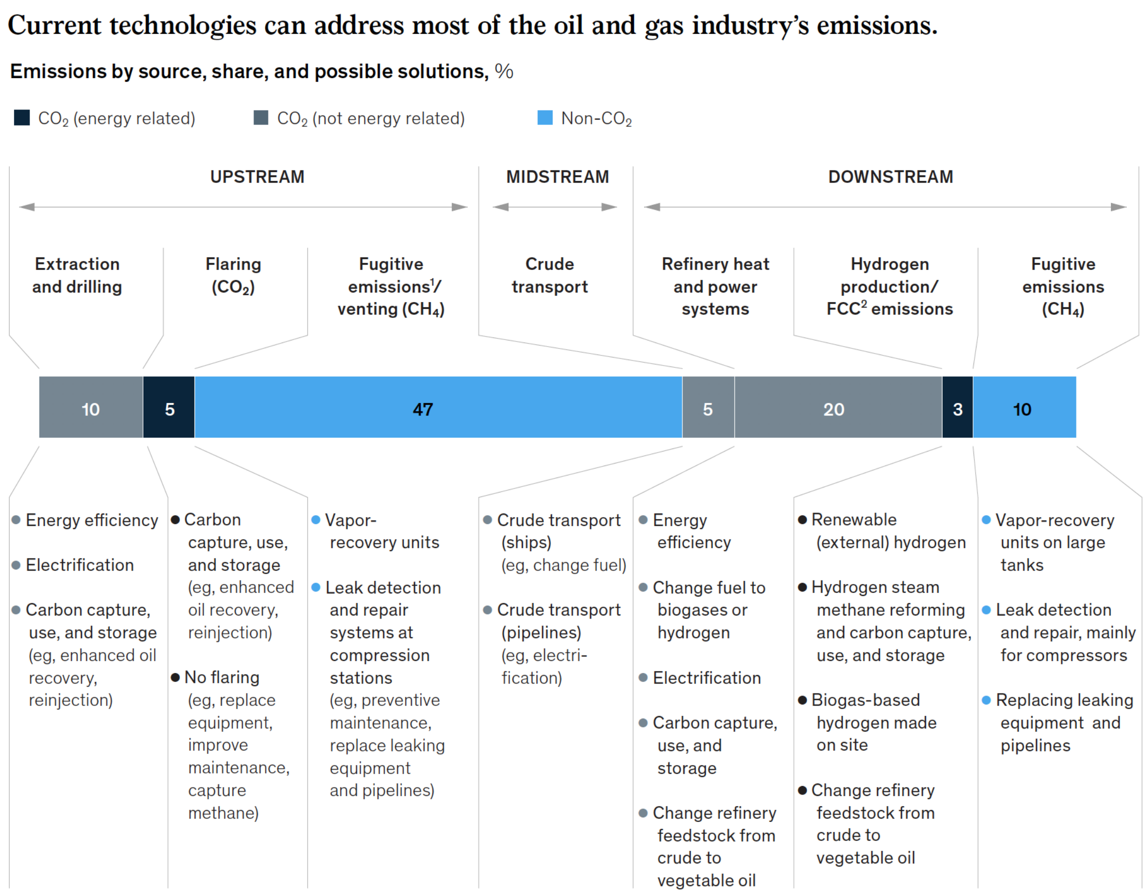
- Oil and Gas Industry accounts for 9% of all human made greenhouse gas (GHG) emmissions and produces the fuels that create 33% of GHG.
- Investors are pushing for more active disclosure of Oil and Gas climate policies and plans.
- In Australia, New Zealand, Canada, Europe, Japan, and the United States sustainable investments reached assets of $30.7 trillion in early 2018, one-third of total investment.
- Renewables are getting cheaper: The cost of solar - both photovoltaics (PV) and utility scale fallen 70% since 2011 with the cost of wind by almost two-thirds. By 2025, competitive with Natural Gas.
- Still no Global Market for Carbon Taxes
- Emissions must be reduced by 3.4 Gigatons of Carbon Dioxide Emissions per Year.
- The oil and gas sector must reduce its emissions by at least 3.4 gigatons of carbon-dioxide equivalent a year by 2050, compared with business as usual (90% reduction). This can be achieved at an average cost of less than $50 per ton of carbon dioxide equivalent. Process changes and minor adjustments that help companies reduce their energy consumption.
- Special initiatives a compnay chooses to reduce its emissions will depend on factors such as geography, asset mix (offshore vs onshore, gas versus oil, upstream ver-

sus downstream, and local policies and practises (regulations, carbon pricing, the availability of renewables and the central grid's reliability and proximity)

- Companies have already adopted techniques that can substantially decarbonise operations (improved maintenance routines to reduce intermittent flaring and vapour recovery units to reduce methane leaks)
- Cutting emissions is not necessary expensive as an offshore operator found that about 40% of initiatives it identified had a +ve NPV at current prices and an additional 30% if it imposed an internal carbon price of \$40 per tonne of CO2 in emissions.
- Utilisation of Carbon Sinks could help Decarbonisation. **Potentially use Carbon Taxes to fund carbon sinks in different geographies**.
- Plants and trees sequester around 2.4 billion tons of CO2 a year.
- Shell offers Dutch customers the opportunity to pay to offset emissions.
- The Cost of Carbon Sinks is uncertain as estimates range from \$6 to \$120 per tonne of CO2 in 2030, depending on the source and the sequestration target.
- Reducing fugitive emissions and flaring cold contribute 1.5 GtCO2e in annual abatement by 2050, at a cost of less than \$15/tCO2e.

Global emissions, by source and fuel type, 2015,[1] %





7.2 What can Upstream Operators do?

- Account for two-thirds of sector-specific emissions. Below, we discuss some ways in which oil and gas companies are taking action.
- **Changing power sources**: Use renewable technology to power facilites instead of diesel fuel or fuel gas.
- Electrify onshore and offshore operations by connecting to the grid.
- Reduce fugitive emissions by applying Leak Detection and Repair (LDAR), installing Vapour-recovery Units (VRU), or applying the best available technology.
- Electrifying Equipment
- Reducing Non-routine flaring through imprived reliability
- Reducing routine flaring through improved additional gas processing and infrastructure.
- Increasing carbon capture, use and storage: This technology is projected to play only a minor role i nthe sector's overall decarbonisation. O and G there are large scale CCUS facilities in commercial operation, four more are under construction with 19 operating and 28 under development. Total CCUS could increase 200 times from existing 40mtCO2e as CCUS already used for advanced oil recovery.
- USA exploring laws and policies to accelerate CCUS development and increasing tax credit.

- **The Clean Gas Project**: A consortium of six oil and gas companies is building what could be the first commercial natural-gas plant with full CCUS capacity.
- Rebalancing portfolios: Looking at the composition of upstream portfolio choices. Highest emitting reservoirs (e.g. Complex Reservoirs - highly viscous, in depth or high pressure and temperature may be at a structural emissions disadvantage.)

7.2.1 Downstream Operators

- Energy Efficiency: Waste-Heat Recovery and Medium Temperature Heat Pumps in Refineries.
- Green Hydrogen: Hydrogen production through electrolysis has become both more technically advanced and less expensive.
- Green Hydrogen is not a speculative technology in oil and gas. Shell and ITM power, a UK-based energy storage and clean-fuel company, are building the world's largests hydrogen electrolysis plant at a German Refinery, with support from the European Union.
- Revenue will come from selling hydrogen to the Refinery, which will use it for upgrading its products and for grid balancing payments to the German transmission system.
- **High Temperature Electric Cracking**: Use electric coils instead of fuel gas to provide heat.
- **Use Greener Feedstocks**: Biobased feedstocks or recycled plastic materials (through pyrolysis or gasification).

Oil and Gas will play an important role in the global energy transition, facing the future is a matter of strategy according to the article. As transparency increases, so may expectations. Customers, employees and investors are already starting to distinguish who are leading the industry. All information in this section is cited from [1].

8 Pricing Carbon: The Challenges

8.1 Introduction

- A global carbon tax is to price the externalities caused by greenhouse gas emissions according to the polluter-pays-principle
- Politics are a major problem. unpopulr policies lead to denial or procrastination in passing useful legislation.
- Lobbyists create significant barriers as can influence politics in a very direct way.
- Unilateral action is slow and negotiations have several times coem to a standstill when burden-sharing and fairness are reported.

8.2 Carbon Tax

- The most-cost efficient policy in order to reduce carbon emissions (more so than regulation of technology, products, and behaviours). It affects production levels and consumption levels too.
- Carbon Tax encourages the continous reduction of polution rather than Cap and Trade when encourages down to a Cap.
- A Carbon Taxes have existed internationally for 25 years. Finland was the first (1990), followed by other Nordic Countries. Only a handle of countries outside the nordic countries haver implemented a Carbon Tax of at least \$10 tCO2e to date: (UK, Ireland, Switzerland, and BC in Canada) (More likely in another source)
- Sweden's implementation of the Carbon Tax (\$130/tCO2e) has been effective. It applies in particular to transport, where gasoline and diesel are taxed strictly in proportion to carbon emissions, but also to commercial use and residential heating as well as partially to industry.
- In sweden, 40% of final energy consumption comes from Buildings. This heating principle will change on location.
- The tax helped phase out fossil fuels for district heating use, switching to recycled and sustainable energy production.
- District heating output almost doubled in the district heating sector while carbon emissions dropped 75%.
- The author says a carbon tax alone is not affective in reducing carbon taxes as their will be a reliance on a combination of instruments with different targets simultaneously.
- Sweden saw the economy emissions decrease 9% while the countries economy experienced a growth of 51%. There was a strong decoupling between the two.
- These figures only took into account products consumed within the country. Greenhouse gas Emissions have decreased by 22% since 1990 since 1990.
- **A good output metric could be CO2 / GDP**.

8.3 Political Challenges with a Carbon Tax

- In 1990, a political tax failed to be implemented for several reasons. Ministers of Finance were notoriously unwilling to compromise on taxes and give up their prerogative on tax issues to supra-national authorities as views as a national convern. They were reluctant on letting the EU decide on yet another area of policy.

8.3.1 Global Reasons

1. Strong lobbying by Fossil Fuel Stakeholders
2. Opposition from the Public as this raises prices
3. Transparency as to the effects on winners and losers compared to the much less visible costs of regulation

4. A perception that taxes reduce welfare and increae unemployment due to lower levels of consumption and production.
5. Possible institutional path dependencies that led to favouring cap and trade.

There were a number of different responses:

1. Removal of Fossil Fuel Subsidies. These subsidies harm the environment in various ways. they also discourage investment in renewable energy and efficiency, and impose a large fiscal burden. They can also go towards other public funing initiatives. Inefficient in supporting disadvantaged groups with most of the benefits lying with the rich.
2. Fuel Consumption: Implement a fuel tax. Fuel has approximately -0.1 to -0.25 price elasticity in ST and -0.7 average in LT.
3. Cap and Trade, and Regulation: Regulate quantities of emissions and not prices (Advantage for a regulator). Buy/sell excess permits. Permits are allocated either by auction, free allocationm or a mix of both approaches. Revenue is made in auctions but not free allocation.
4. **EU Emissions Trading Scheme (ETS)**: World largest CAT programme. (45% of total GHG Emissions). Emission reductions have been modest. Ironically, the major driver for decreasing global emissions was the financial crisis, not the ETS (COVID-19????). ETS effectiveness compromised due to a latent allocation of permits in the first two phases.
5. Carbon CAT programmes have been unsuccessful as CAT limits too high woth corresponding low prices to achieve certain reductions. There is heavylobbying to keep industry CAT limits high. CAT has been found to be regressive.
6. Politicians are worried that a tight cap will hurt their industries. CAT unlikely to work with other policies as move in different directions.
7. The most contentious part of international negotiations is to link locale schemes without full agreement on targets as no-one wants to lose. Most negotiations focus on an quantative allocation or undertaking by different countries.
8. **Promoting Renewable Energy**: New energy infrastructure (from Renewable technologies) is equally important to reducing Carbon Emissions. The price gap in Renewables and Fossil Fuels is quickly decreasing. You can induce renewables to be cheaper than fossil fuels through a carbon tax.
9. Germnay is a good example of this power transmission. The transition mainly focuses on wind and solar (The most cost-efficient renewable technologies to date)

Conclusion

- Carbon Taxe fell politcally out of reach
- Cap and Trade - Set to quantity instead of price but difficult to negotiate the cap. India benefit if caps set on a per capita basis while US benefot through grandfathering.
- Professors (Academics) should shift focus to prices

- Price floors should be implements with quantities, possibly a tax per carbon tonne of carbon.
- Price floor increases global efficiency of carbon mitigation and reduce the risk of leakage and pollution havens, while at the same time the market would receive signals to invest in renewable technologies and emission abatement.

All information from this section is cited from [5].

9 References

References

[1] Chantel Beck et al. “The Future is Now: How Oil and Gas Companies can Decarbonixe”. McKinsey and Company: Oil and Gas Analysis. 2020.
[2] BusinessNZ Energy Council. *New Zealand Energy Scenarios - Navigating Energy Futures to 2050*. Tech. rep. 2015.
[3] BusinessNZ Energy Council. *New Zealand Energy Scenarios - Navigating Energy Futures to 2060*. Tech. rep. 2019.
[4] Joao Pedro Gouveia et al. “TIMES PT: Integrated Energy System Modeling”. Conference: IT4 Energy, At Lisbon. 2012.
[5] T Sterner and G Kohlin. “Pricing Carbon: The Challenges”. PhD thesis. 2015.