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SIT-Hatch-EMC Thinktank Roundtable Session

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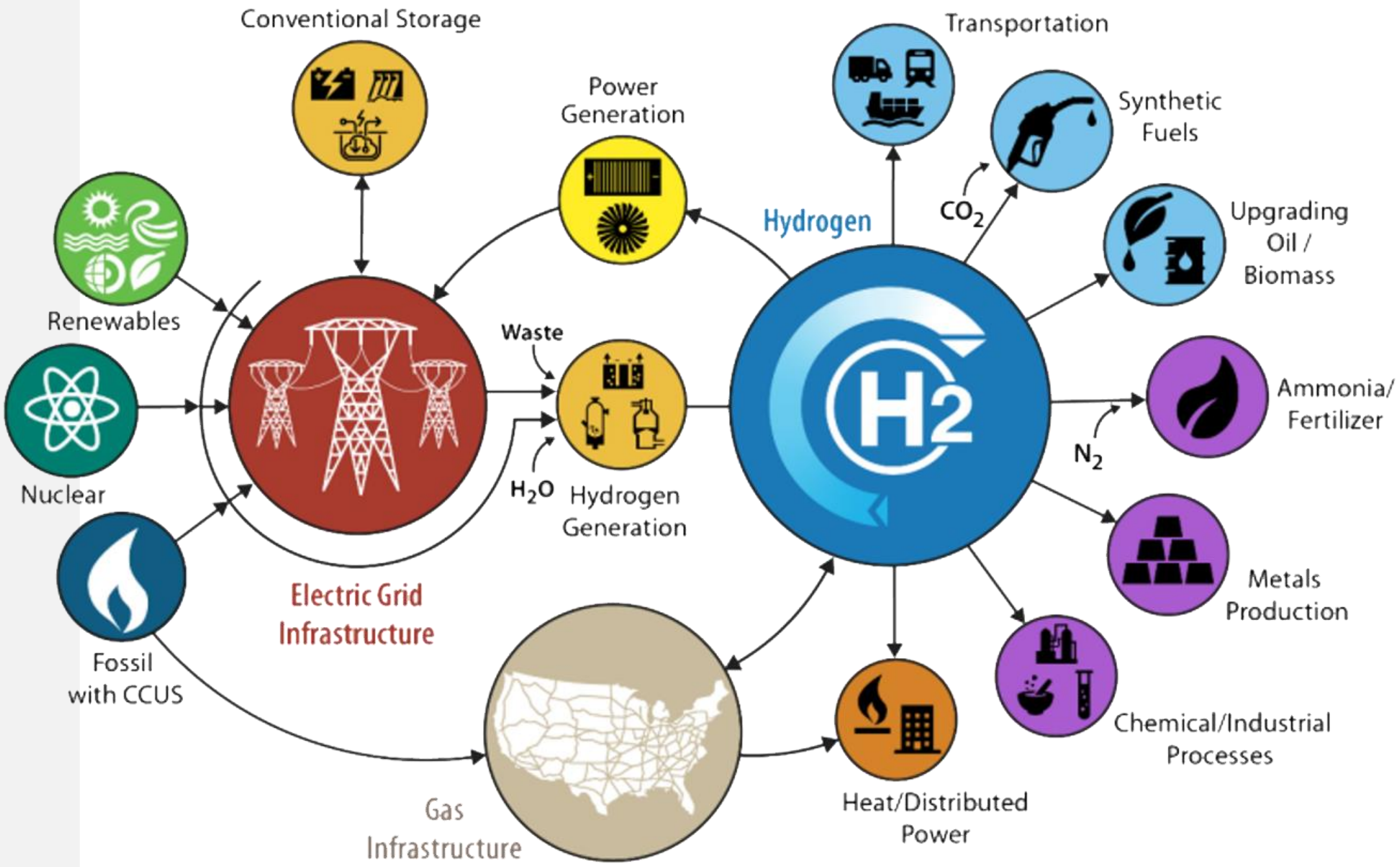
The role of hydrogen and ammonia storage in grid stability



Lana van Wyk

October 2022

Large scale hydrogen production will support deep decarbonization



Source:
USA DOE Green Hydrogen Strategy and Roadmap

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Large scale investment in renewable energy generation will underpin hydrogen production

Renewable energy generation

	Capital Cost	Installed capacity	Total
	A$M 1.3 /MW	14 GW	A$ 18 bn
			OR
	A$M 1.6 /MW	9 GW	A$ 14 bn

Hydrogen production & Storage (440 kt)

	Capital Cost	Installed capacity	Total
 NEL PEM Electrolyzer (Source: NEL)	A$ 1800 /KW	5.6 GW	A$ 10 bn
			and
	A$ 67 /kg H2	37* kt	A$ 2.4 bn

Notes: *$ 67 / kg for liquid storage, $ 1000/kg for vessel storage - confidential Hatch analysis*
Assume one month's storage capacity

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HVDC For the Import of Renewable Energy

SIEW 2022 Roundtable

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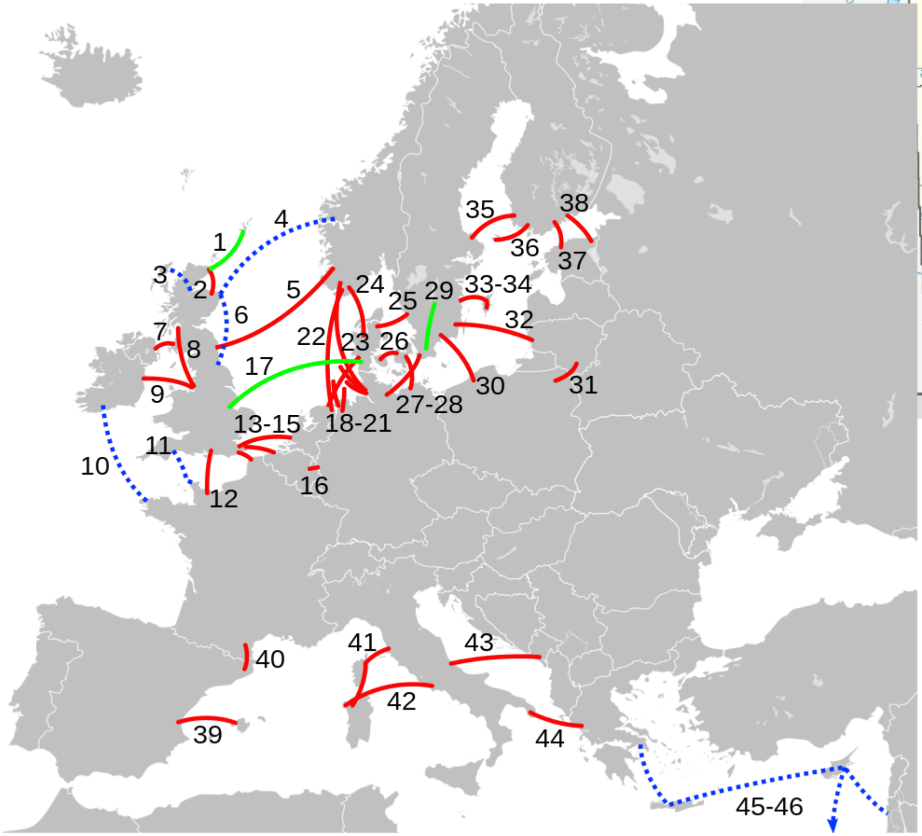
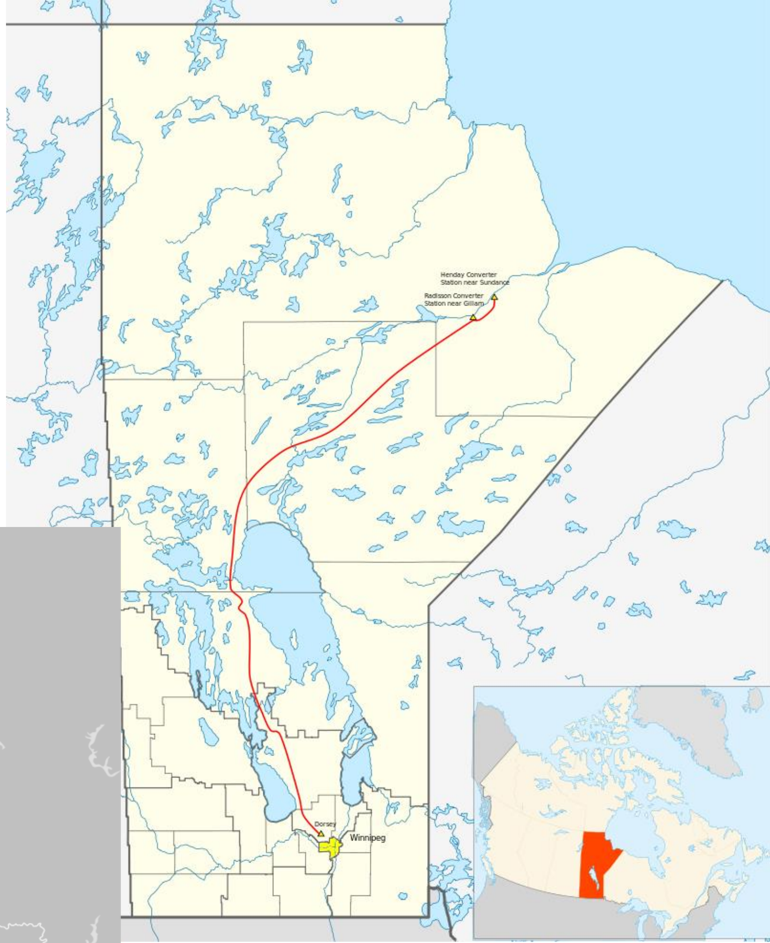
HVDC History

- HVDC has been used since the 1960’s to move large amounts of renewable energy
- The technology is suited to move large amounts of power over long distances
- Can happen between asynchronous systems





[HVDC Europe annotated-2019 - List of HVDC projects - Wikipedia]

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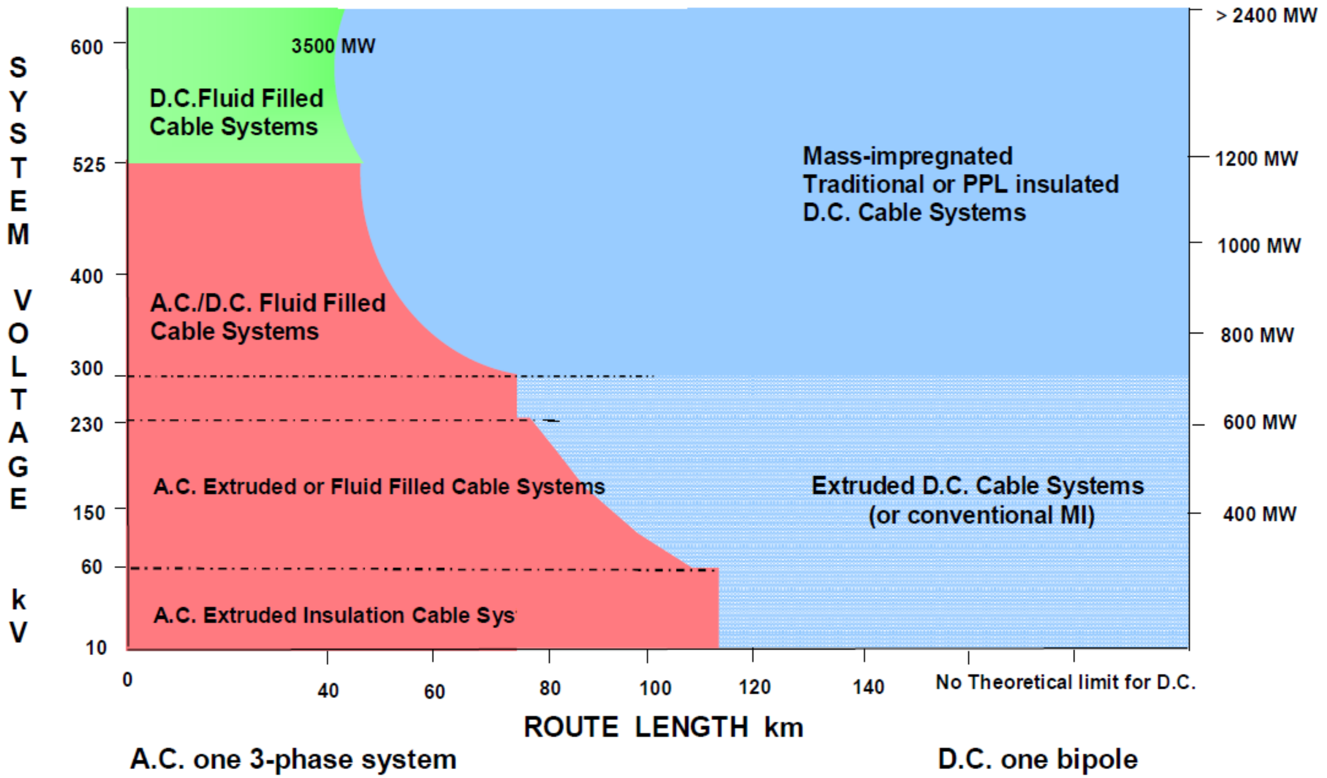
HVDC Technology Application

- Moving power undersea(land) over moderate to long distances

(DC has theoretically no distance limit)

Power Level	DC	AC
1000MW	2 x 320kV DC cables	3 x 3ph 220kV AC cables 9 x 1ph 220kV AC cables
1300MW	2 x 320kV DC cables 2 x 400kV DC cables	4 x 3ph 220kV AC cables 12 x 1ph 220kV AC cables
2000MW	2 x 500kV DC cables	5 x 3ph 220kV AC cables 15 x 1ph 220kV AC cables



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HVDC

- Most importantly, the ‘silent’ energy evolution of HVDC technology has made it feasible to connect grids over much longer distances

Voltage improvements

XLPE cable voltages have increased, reducing losses
The cable voltage has increased from **300 kV** to **525 kV** over approximately 6 years

Reliability improvements

Fault rates have reduced, increasing reliability and availability
Fault rates have decreased by **80%** over last 20 years.

Operational improvements

Depths of cable laying have increased to

3,000 metres

for proposed submarine power cable projects to be constructed within the next 3-4 years

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Thank you.

For further information or discussions, please contact:

Dan Kell, email: dan.kell@hatch.com
Senior Director – Power System Studies & HVDC

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Securing SG Electricity Imports: Battery Energy Storage & System Security

SIEW 2022 Roundtable C

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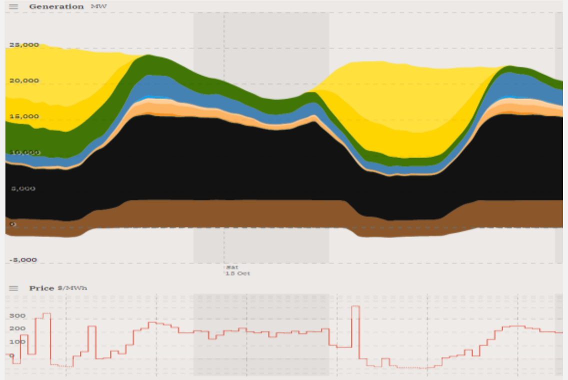
Review of BESS Use Cases/Value Streams

Supply Reliability, Energy Market

1. Energy **time-shifting**/peak-shaving/trough-filling, energy **arbitrage**, **flexible Demand** Response
2. **Firming** intermittent VRE generation, market capacity trading
3. Reduce thermal **spinning reserve** (balancing) requirements
4. **Reduce RE curtailment**/capturing spilled RE
5. Network **investment deferral** (e.g. Virtual Transmission Line), constraint alleviation
6. Reduction of retail energy import tariffs, demand charges (distributed BESS, VPP)

System Security, Grid Stability Ancillary Services

1. **Frequency control -** regulation & contingency (FFR, virtual inertia, primary and secondary) response, System Integrity Protection Schemes (SIPS/SPS)
2. Voltage control (regulation, contingency/FRT support)
3. **Islanding/microgrid-forming**
4. Transmission System restart/Black Start



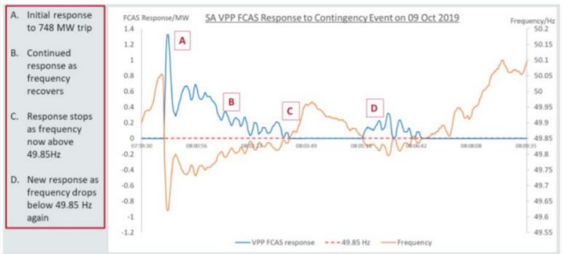
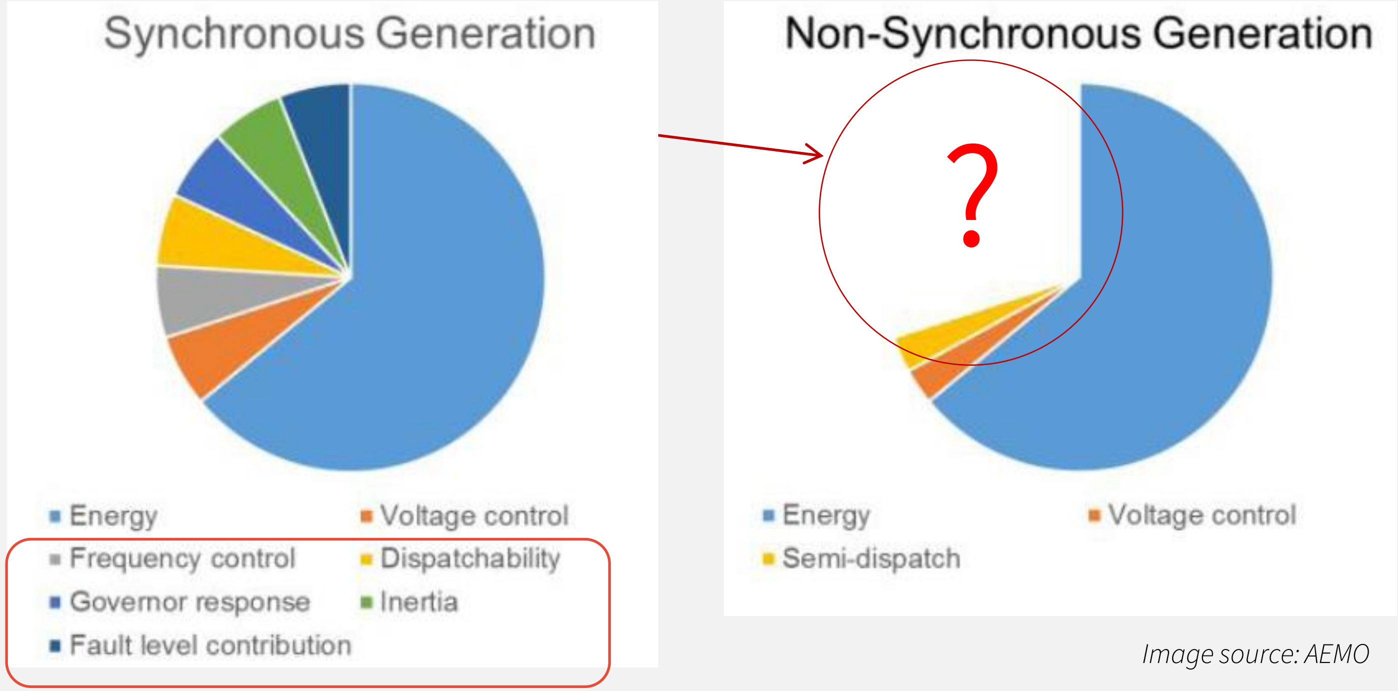


Image source: AEMO Virtual Power Plant Demonstration Knowledge Sharing Report #1, March 2020; Public/open source

Growth of VRE Generation & System Security

- VRE displacement of synchronous generation -> reduction in dispatchability, grid stability support
- BESS as dispatchable IBR to backfill system security support



Traditional synchronous plant

Image source: AEMO

Technical & Commercial Use Cases for AUS BESS (2022)

- Levelised cost of unsubsidized BESS still significant compared to solar, wind ($150-200/MWh vs $30-60/MWh)
- Majority of BESS revenue in the NEM from frequency control markets (FCAS)
- Still reliant on subsidies/grid support contracts
- Value of Dist. BESS/VPP's – timeshifting DER, avoided retail tariffs Behind-The-Meter/Transmission Use of Systems (TUOS)

Victorian Big Battery: ***Virtual Transmission Line, 250MW SIPS***
300MW/450MWh

ESCRI-SA: ***Advanced Grid Services (Grid-forming, Virtual Inertia, 2x Fault level support)***
30MW/8MWh

Dist. BESS/Virtual Power Plants: ***Islanding, contingency FCAS & dispatch***
~700MW/1900MWh

Market Revenue ($M) (FY2018-FY2022)

Refs: Jonathan Dyson, "Utility Scale Battery Storage in the Australian National Electricity Market", CIGRE ELECTRA article. Oct 2022; G Kuiper, "What Is The State of Virtual Power Plants in Australia", IEEFA article Mar 2022

Considerations for Future BESS/ESS Deployment in SG

1. Power System Operational and Planning Philosophy – synchronous vs asynchronous
2. Role in high RE system security control/protection schemes
3. Fit-for-purpose power system and market modeling analysis
4. Appropriate technical requirements, regulation and market design to provide long-term BESS investment certainty
5. Future role of distributed BESS (VPP, V2G) in supporting system reliability and security
6. Mechanisms to support next generation, long duration ESS technologies (H2, thermal, CAES, etc.)

Image source: Public

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The Role of Energy Imports to support Singapore Decarbonization Goals - Markets

Zhenhui Li
Chief Economist

Outline

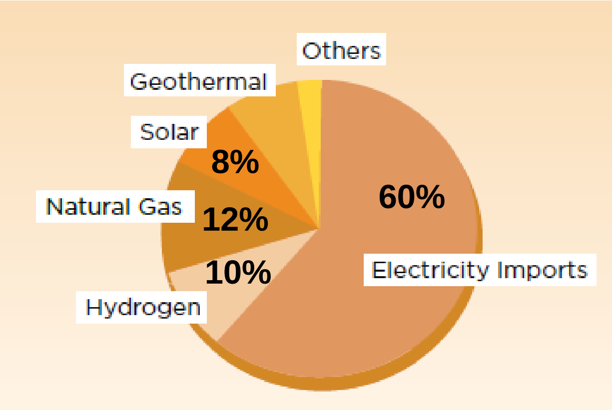
1. **Singapore Government's Vision for a Net-Zero Power Sector and policies for the Energy Transition**
2. Possible evolution for National Electricity Market of Singapore (NEMS) to accommodate new technologies
3. Conclusion

2050 Vision Plans – Net-Zero Power Sector

Key Message on 2050's Fuel Mix

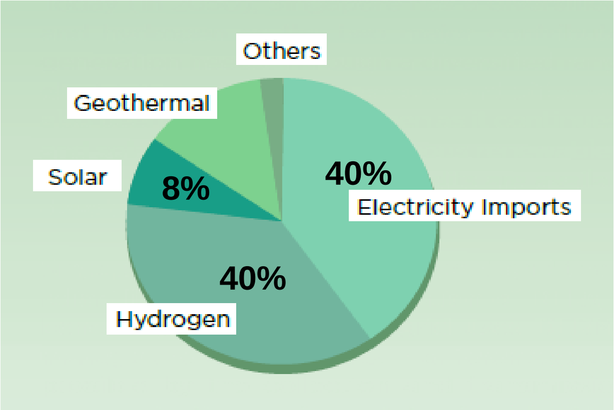
Electricity Imports & **Hydrogen / Natural Gas (with CCS)** will be the key resources to allow Singapore to achieve the net-zero target in 2050 regardless of the scenarios. Therefore, the costs of transition will largely be determined by these 2 key resources.

Climate Action Bloc (CAB)



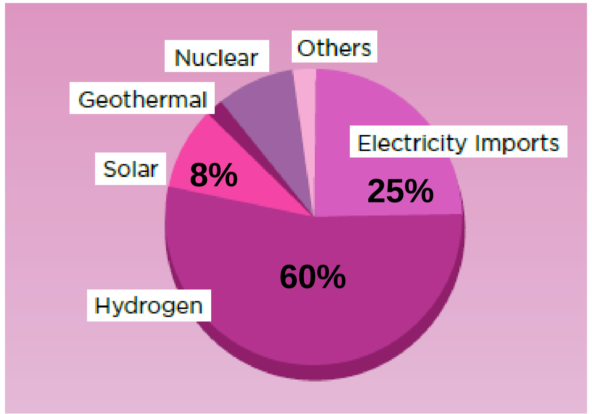
Attribute	Ranking
Energy Security	★
Sustainability	★
Affordability	★★★

Clean Energy Renaissance (CER)



Attribute	Ranking
Energy Security	★★
Sustainability	★★★
Affordability	★★

Emergent Technology Trailblazer (ETT)



Attribute	Ranking
Energy Security	★★★
Sustainability	★★
Affordability	★

Energy Market Company

A Glance of Government's initiatives on Energy Transition

Electricity Imports

- Imports Trial of 100MW each
  - LTMS-PIP, 2022
  - Malaysia Imports (WIP)
  - Indonesia Imports (WIP)
- Large-Scale Imports up to 4GW
  - RFP 1 & 2
  - Penalty Framework consultation
  - Imports Backup consultation

New Technologies

- Geothermal
  - Geo Physical Investigation, 2022
- Hydrogen
  - Hydrogen imports and downstream applications for Singapore, 2021
- Carbon Capture Storage and Utilization (CCSU)
  - CCSU: Decarbonization pathways for Singapore energy and chemical sector, 2021
- Nuclear
  - Energy 2050 Report, 2022

Energy Storage System

- Integration of ESS into National Electricity Market of Singapore (NEMS), 2018
- ESS Regulatory Sandbox with SPPA, 2018
- BESS
  - 2.4MW/2.4MWh battery, 2021
  - 1.7MW/2.0MWh, 2022
  - 200MW/200MWh battery, end-2022

Solar

- Solar Target
  - 1.5GWp & 2GWp by 2025 & 2030
- Solar Participation
  - SP: SCT & ECIS
  - EMC: NEIGF & SWEM MP
- Aggregating of Standalone IGS into a Pseudo GSF
- Intermittency Pricing Mechanism (IPM)
  - Allocating appropriate system costs to manage solar intermittency of solar facilities (WIP)

Demand Side Management

- Existing Schemes
  - Interruptible Load (IL) [Reserve], 2004
  - Demand Response (DR) [Energy], 2016
- Review of the DR in NEMS
  - Consultation, 2020
  - Sandbox to encourage more DR participants in NEMS (WIP)

Outline

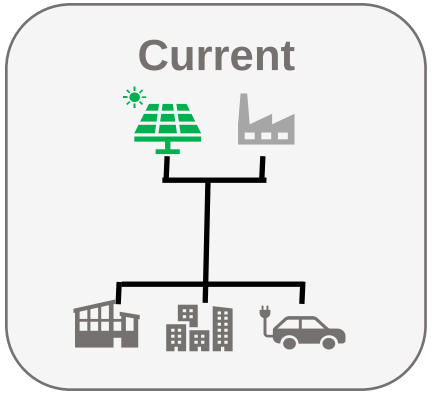
1. Singapore Government's Vision for a Net-Zero Power Sector and policies for the Energy Transition
2. **Possible evolution for National Electricity Market of Singapore (NEMS) to accommodate new technologies**
3. Conclusion

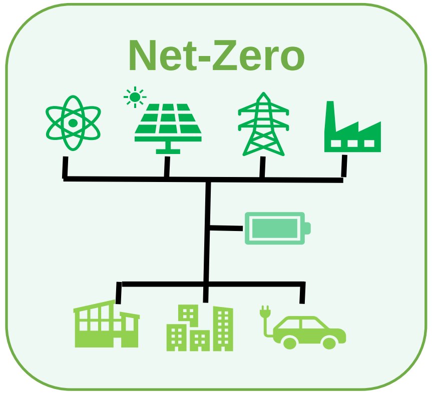
Market as a tool to reach Net-Zero by 2050

- **What can an Electricity Market do?**
  - Determine prices based on supply and demand
  - Ration electricity via price signals
  - Allow customers’ choices on the type of electricity and services
  - Create transparency in price to allow informed decisions by the producers and consumers

- **What can’t an Electricity Market do?**
  - Prescribe a time for Singapore to reach net-zero
  - Determine the exact generation technology mix to reach net-zero before 2050
  - Protect consumers from high volatile electricity prices due to a volatile primary energy shocks
  - Commissioning/Decommission of new/old generation units in a timely and orderly manner

National Electricity Market of Singapore Evolution





- **Current electricity landscape**
  - Dominated by natural gas thermal plants which are dispatchable
  - Relative Inelastic demand

- **Current Market design**
  - Energy-only market with 4 real-time products and 1 active ancillary service contract
  - Self-sufficient

- **Future electricity landscape**
  - Dominated by net-zero technologies by electricity Imports, hydrogen, BESS
  - A more flexible demand

- **Future Market design**
  - Multi-revenue streams other than existing market revenues, such as **REC, Capacity payments**
  - Self-sufficient/Dependency (??)

Energy Market Company

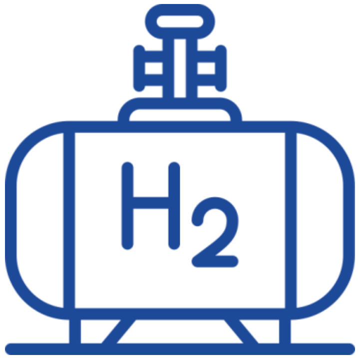
How can NEMS evolve to accommodate Electricity Imports

- **Considerations (For)**
  - Proven technology and commercially viable
  - Allow access to ASEAN and Australia renewable resources
  - Dispatchable and reliable

- **Considerations (Against)**
  - Subject to geo-political risk
  - Less control over generating units as they are not in Singapore

- **Potential New Revenue Streams**
  - Renewable Energy Certificates (REC)
  - Revenue-Support via Contracts for Differences (CfD) or Performance Contract (PC)
- **Potential Costs for Imports**
  - Back-up costs for imports ~ 15 SGD/MWh
  - Higher reserve costs
- **Potential Market Changes**
  - Creation of a day-ahead market to support trading of electricity within ASEAN

How can NEMS evolve to accommodate Hydrogen



- **Considerations (For)**
  - Highly storable (enhances energy security)
  - Allow access to countries beyond ASEAN and Australia for hydrogen
  - More control over generation units as they are in Singapore

- **Considerations (Against)**
  - Subject to geo-political risk
  - Higher costs compared to other types of renewable or low carbon energy sources
  - Refurbishing costs for infrastructure to accommodate hydrogen may be high

- **Potential New Revenue Streams**
  - Capacity Payments for hydrogen enable units?
  - Renewable Energy Certificates (REC) – Dependable on fuel mix
  - Government grants and investment
- **Potential Costs for hydrogen**
  - The higher production costs should be reflected in real-time market
- **Potential Market Changes**
  - N.A.

How can NEMS evolve to accommodate Energy Storage Systems (ESS)

- **Considerations (For)**
  - Useful tool to manage solar intermittency and providing ancillary services for system reliability
  - BESS is preferred as they are stackable (space-optimized) and modular (scalable)

- **Considerations (Against)**
  - BESS are expensive to be deploy commercially
  - Lack of other revenue steams/mechanism to price BESS’ services

- **Potential New Revenue Streams**
  - Capacity payments?
  - New real-time services such as Fast-Response products or flexibility products?
  - Government grants and investment
- **Potential Costs for BESS**
  - Grid charges when withdrawing from grid as load
- **Potential Market Changes**
  - BESS modelling
  - Higher frequency dispatch periods (i.e 5 minutes)

Outline

1. Singapore Government's Vision for a Net-Zero Power Sector and policies for the Energy Transition
2. Possible evolution for National Electricity Market of Singapore (NEMS) to accommodate new technologies
3. **Conclusion**

Conclusion

- **Singapore's electricity markets need to evolve faster to**

  - Meet Singapore's government ambition of net-zero targets by 2050 while balancing other objectives such energy security, affordability for consumers
  - Accommodate the characteristic of a net-zero fuel mix consisting of BESS, Imports, Distributed Energy Resources (DERs), solar which usually behave differently from the thermal units
  - Reflective wholesale prices to attract 'green' energy investments

Thank you

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Sustainable Development Policies from Energy Transition: Impacts and Perspectives from Environmental, Social and Governance

Dr Seck TAN

SINGAPORE INTERNATIONAL ENERGY WEEK 2022

Marina Bay Sands Room 4311-4312 Singapore
28 October 2022

The Next *Seven* Minutes

Sustainable Development Policies from Energy Transition: Impacts and Perspectives from Environmental, Social and Governance

- Introduction
  - ESG Timeline
  - Growth *versus* Development
  - Sustainable Development
- Carbon Reduction
  - Energy Transition
- Energy Transition
  - The Policies

Extreme Weather

Snow Blizzard

Volcanic Activity

Tsunami

Environmental Crisis

Transboundary Haze

Flash Floods

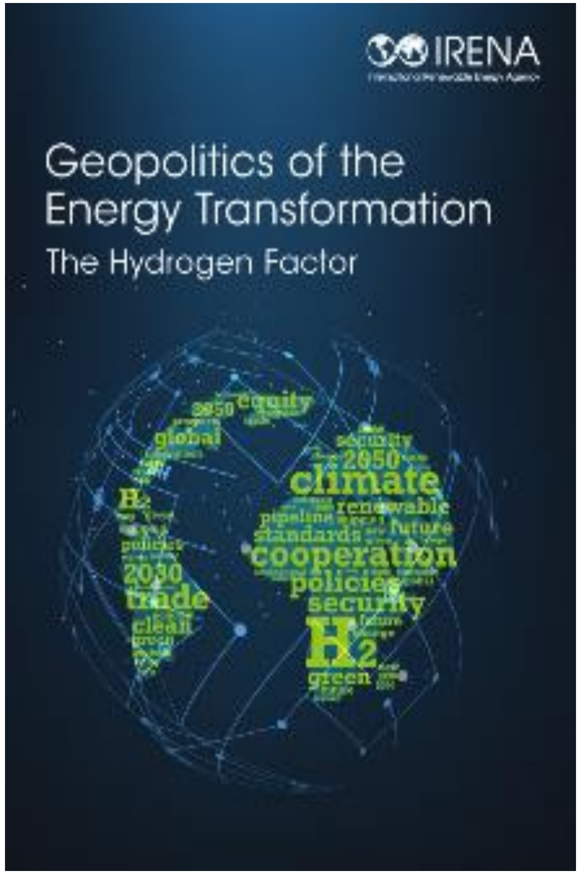
Forest Fires

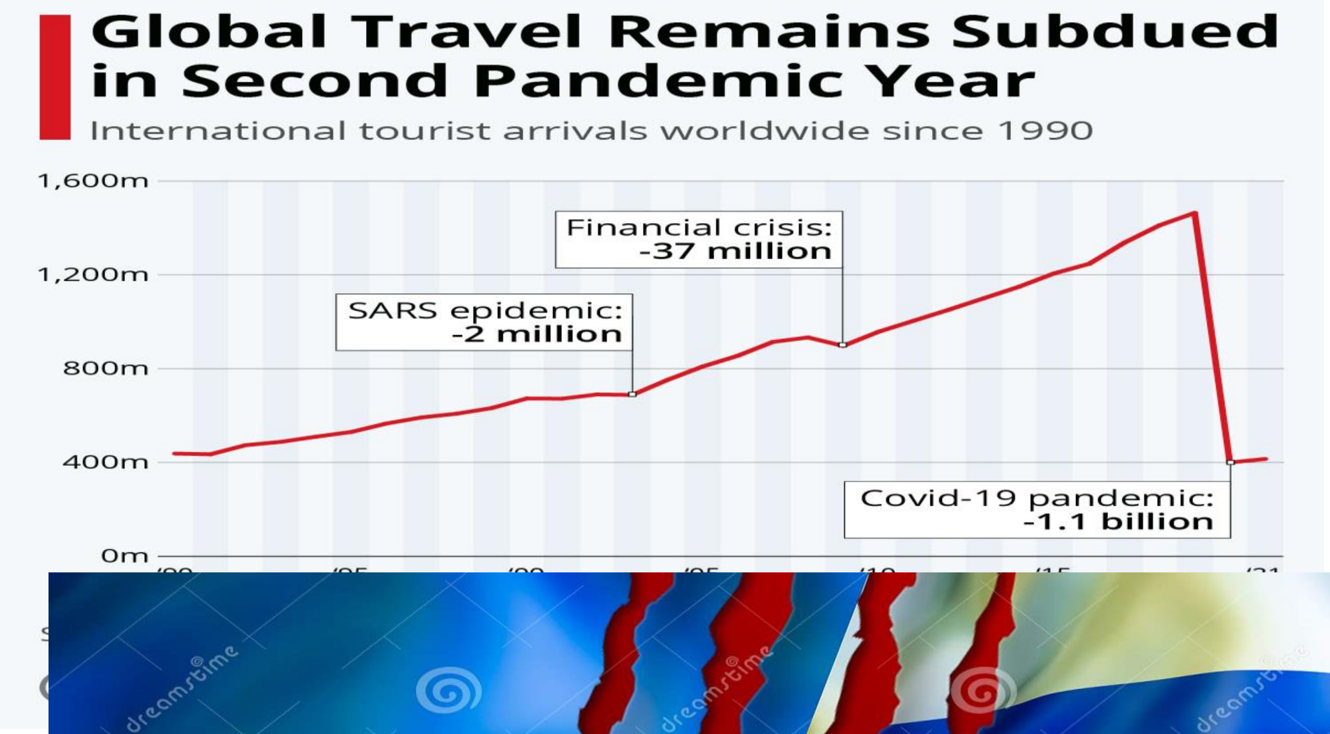
Others (*not exhaustive*)

Geopolitics

Pandemic

War





ESG Timeline

ESG Timeline

- 50s – 60s: Pension investment in healthcare and housing; Vietnam War (Anti-War Campaigns and Clean Air Act to protect the environment and social facets)
- 70s: Shareholder Value Theory by M. Friedman and evolvement of Corporate Social Responsibility (CSR)
- 80s: "Comprehensive Anti-Apartheid Act" which outlawed investments in South Africa
- 90s: Social Index populated by firms with ESG as priority; UN's environmental treaty in Rio de Janeiro ('92) operationalized in Kyoto ('97) and effective in ('05)
- 2000s: UN Global Compact ('00) where firms focus on human rights, labor, environment, and a Guideline ('04) to incorporate ESG as part of firm strategies
- 2011: Sustainability Accounting Standards Board (SASB) as ESG framework
- 2015: UN Paris Agreement and Sustainable Development Goals (next slide)
- 2020: Firms (driven by the public) to prioritize diversity and inclusivity due to economic disparity and health inequality

- *2021: Markets react positively to firms with ESG commitments*

Source: https://npengage.com/companies/esg-history/

Sustainable Development Goals

Source: https://www.un.org/development/desa/disabilities/envision2030.html

Anti-ESG: A Norm?

- 50s – 60s: Pension investment in healthcare and housing; Vietnam War (Anti-War Campaigns and Clean Air Act to protect

What is in it for the Energy Sector?

- 70s: Shareholder Valu ment of Corporate Social Responsibility (CSR)
- 80s: "Com
- 90s: MSCI ntal treaty in Rio de J
- 2000s: UN ent, and a Guideline
- 2011: Sust
- 2015: UN I
- 2020: The economic disparity a


10/17/22, 10:14 PM

Anti-ESG ETF gets off to a roaring start | Financial Times

Latest news on ETFs

ETF Hub Exchange traded funds

Anti-ESG ETF gets off to a roaring start

Launch coincides with moves by some US states against ESG investing and contrasts with slower progress of similar vehicles in the past

- ~~2021: Markets react positively to firms with ESG commitments~~

Source: https://npengage.com/companies/esg-history/

Growth *versus* Development

Growth *versus* Development

- Growth is expanding the community with natural endowments such as, land and other resources towards a better standard of living via improved economic performance

- Development is enhancing livability for instance, culture and heritage, education, employment, safety, and community development

- Economy utilizes available resources to grow; traditional theories present resources (factors of production) as physical and human capital
  - Environment must also be accounted because an economy remains a subset of the ecosystem

Growth *versus* Development

- Sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland et al., 1987)

- For development to be sustainable, the ecosystem must be maintained and protected

- Natural endowments are finite resources; once they contribute to growth, they cannot be utilized for another purpose

- Therefore,

Growth cannot be sustainable;

it is Development that is Sustainable

Source: Brundtland, G. H., Khalid, M., Agnelli, S., Al-Athel, S., & Chidzero, B. (1987). Our common future. New York

Sustainable Development must balance between twin-nexus of

Economy and the *Environment*

For the energy sector, operational activities must balance against ESG issues (carbon emissions and environmental pollution)

Carbon Reduction:
Energy Transition

Carbon Reduction: Energy Transition

- ESG to strategize infrastructure, operation, and technological factors so that the environment is less impacted
  - E.g., hydrogen, carbon capture, renewable energy, energy storage
- Environment: The pillars of equity, efficiency, and distributive can be used to ensure energy and environmental security
  - E.g., energy consumed, waste generated, and utilized natural resources (green source)
- Social: All human touchpoints in the business
  - E.g., human capital requirements, customers, and local community (reinvestment as a social obligation)
- Governance: Compliance, regulations, and shareholders' interest
  - E.g., tax evasion, lobbying, and asymmetric remuneration

Energy Transition: The Policies

Energy Transition: The Policies

What?

- Addressing the volatility of exchange rates
- Geopolitics (which will continue to destabilize energy markets), and
- Public Private Partnership (PPP)

How?

- Educate (the environment)
- Incentivize (to encourage a behavior)
- Inform (source and sink)
- Penalize *(as a last resort)*

Environment: Air, Land, and Water

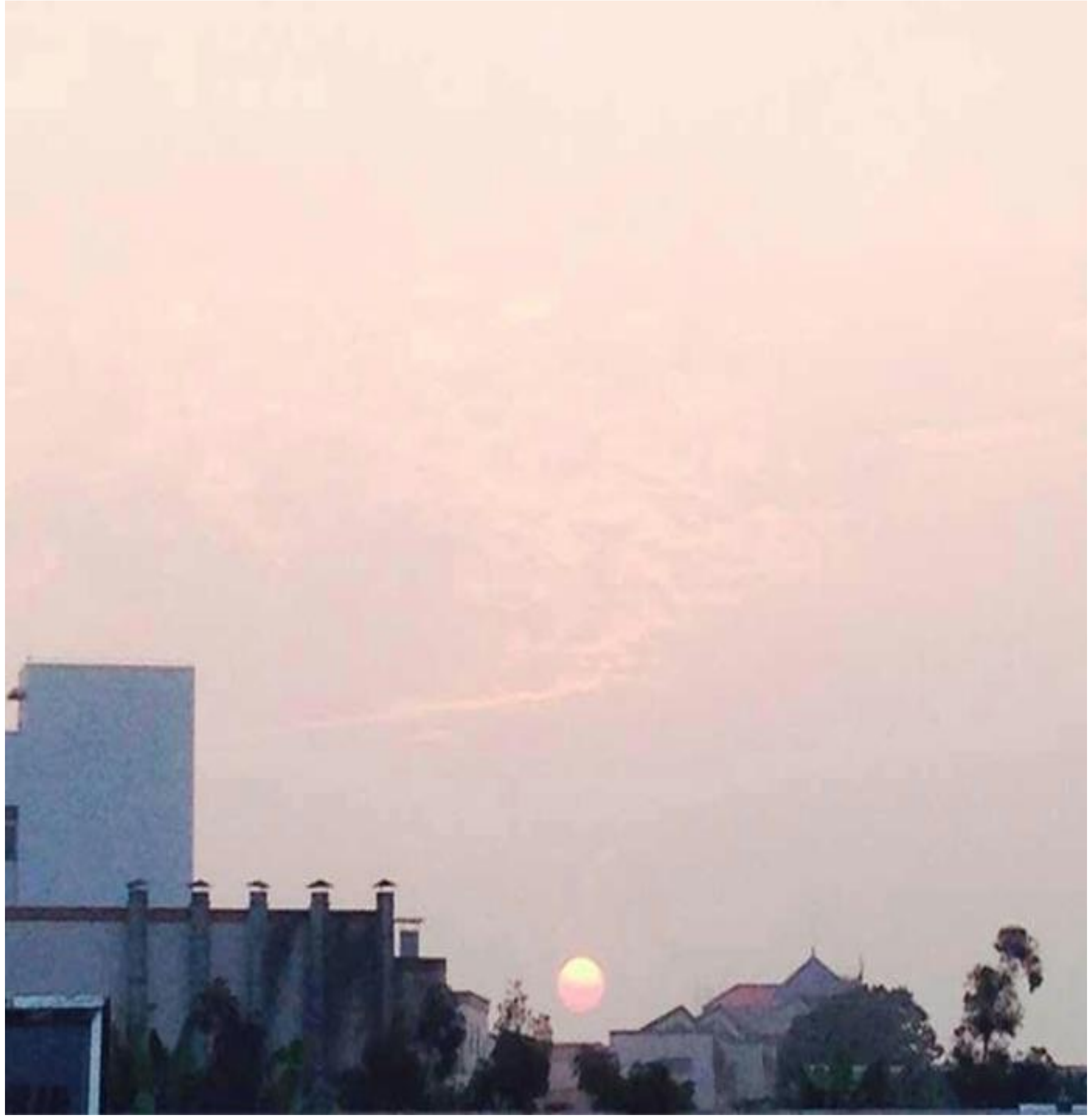
“The land gives us

food and wine from fertile soils.

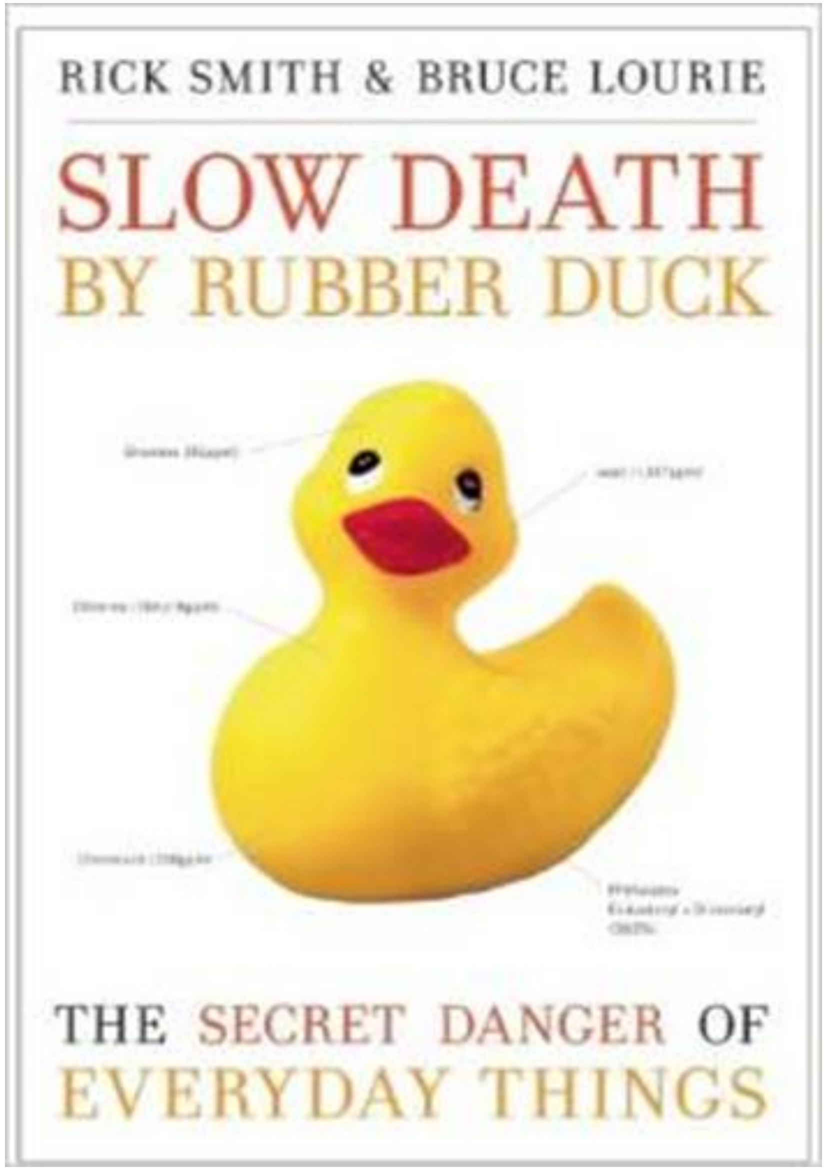
Our waters give us fish, recreation, and a remarkably efficient medium for transportation.

The precious atmosphere yields breathable air, beautiful sunsets and flying space for airplanes.”

Samuelson and Nordhaus (2010)



Environment: Source and Sink



In the book "Slow Death by Rubber Duck" by Smith and Lourie (2009), the human body was used as an analogy to the environmental sink.

The toxins that humans consume from their daily routines remain in the body and pose long-term health risks.

End of Presentation

Thank you!

Seck TAN

Seck.Tan@SingaporeTech.Edu.Sg

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