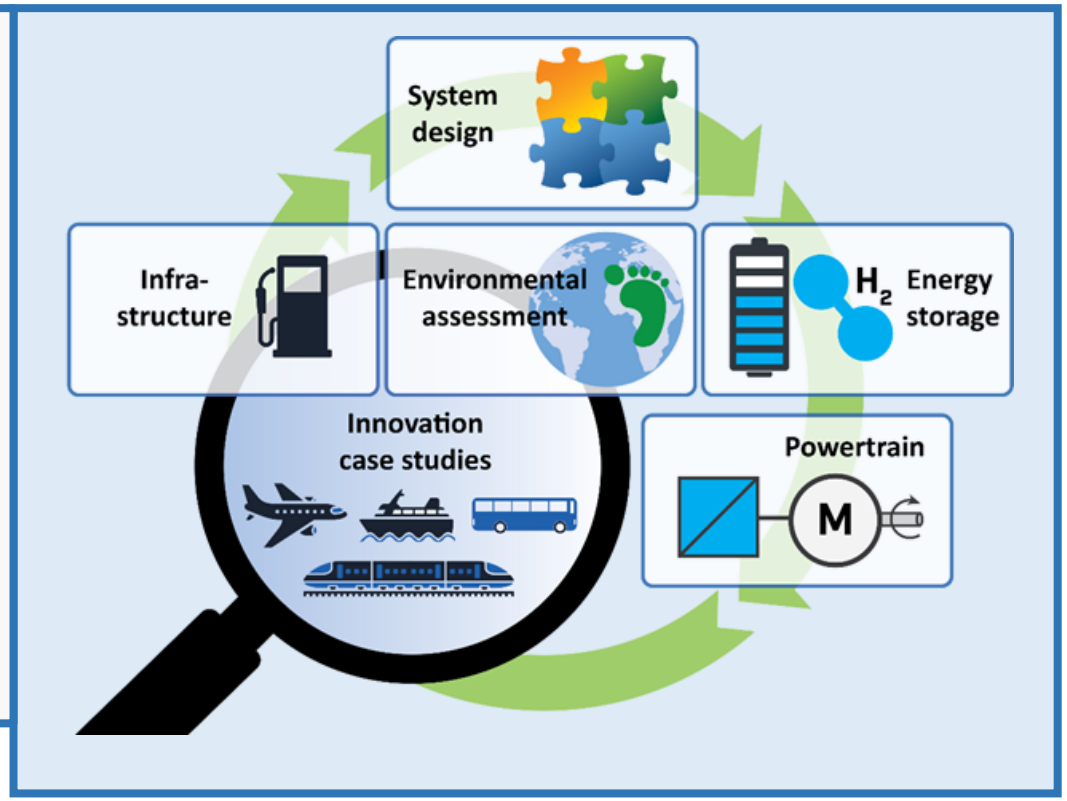

SINTEF
NTNU
NORLED
Holistisk Design og Analyse av Transportsystem
Vibeke Stærkebye Nørstebø

System design and assessment - objectives

- Assess, design and optimise overall technology choices and sizing of infrastructure, energy storage and powertrain systems.

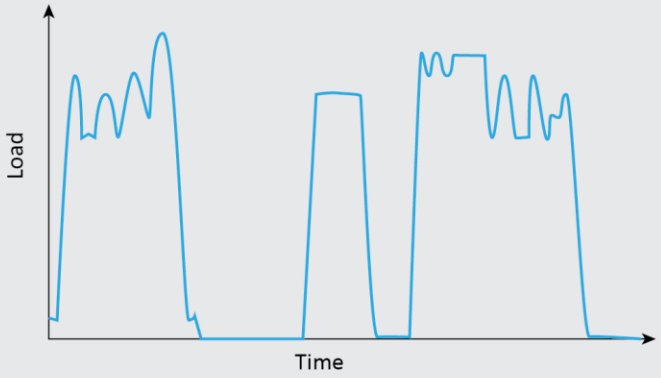
-> Technical characteristics and information as input (energy technology, infrastrucutre)

-> Combined with environmental and social assessment



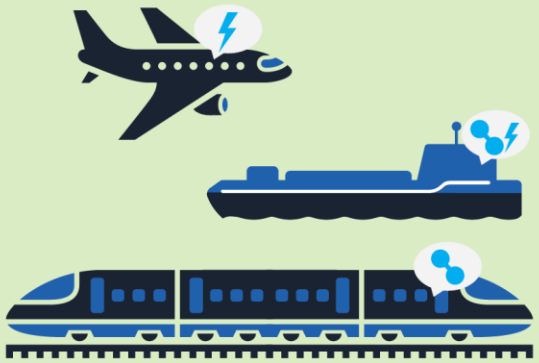
Research challenges

Energy need

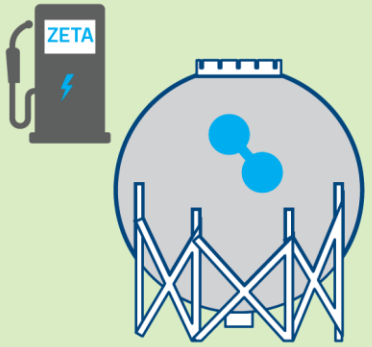


Optimal technology mix

Onboard



Infrastructure



Energy availability

Research challenges, and results

- Lacking **overall assessment to identify and plan in an optimal way** use and **combination of electric and hydrogen-based** technologies

  -> **Characteristics of energy and power use** in heavy vehicles, railways, coastal line vessels and ferries, and short-haul flights.

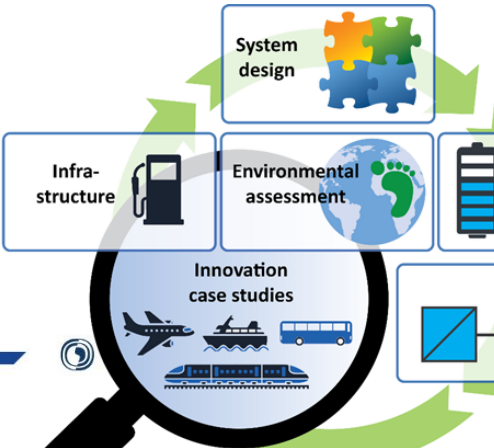
  -> Optimization models for **guiding technology choice, sizing and operation** of zero-emission infrastructure, storage and powertrain for high energy demand.

  -> …based on **relevant and real data** from the industry, and laboratory work

  -> Indicators on relationship of costs and energy/power rating needs

Typical methodologies

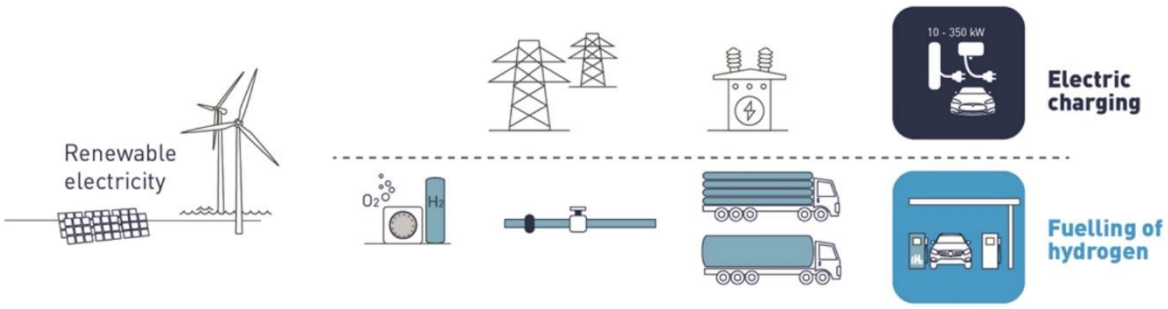
- **Performance curves and data analyses** based on performance descriptions and data from technology providers and experts, laboratory works and literature review
  - different batteries, fuel-cells, hydrogen storages, chargers, etc.
- Load profiles with suitable time and space aggregation
- **Optimization models** for design and operation of vehicle/vessel and infrastructure
  - **Analyses of business models**
- **Learning curves** for new technologies
- **Scenario and feasibility studies**
- **Socio economic studies and ripple effects**



System perspective

- System perspective
  - Infrastructure
  - Location
  - Technology and sectors and sector coupling
- Complexity

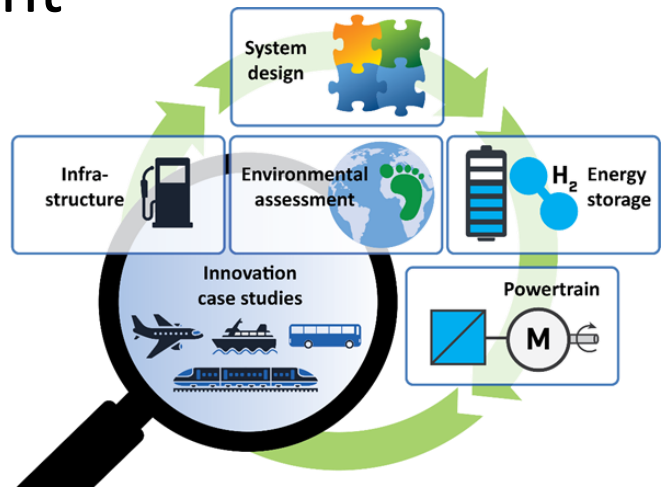
  -> Mathematical models for decision support



Source: Smart2zero.com, https://www.smart2zero.com/news/battery-or-fuel-cell-researchers-calculate-infrastructure-costs

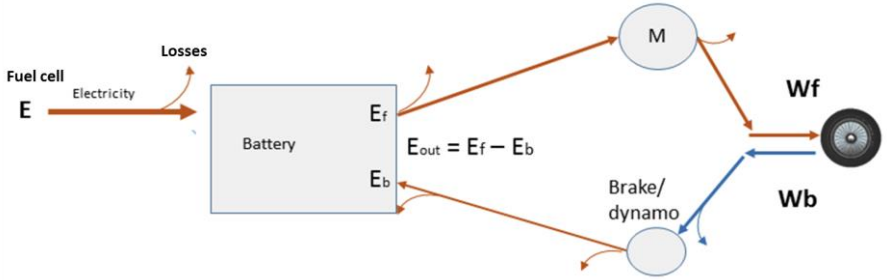
Potential wider impact

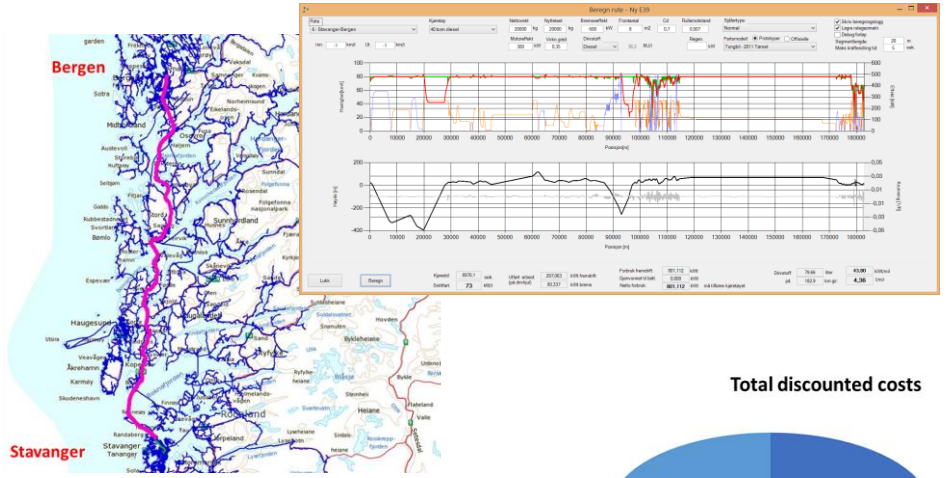
- **Roadmap for technology transition** towards fossil-free high energy demand transportation **showing specific technology and economic consequences** for different sectors
- Opening for **new possibilities and changes in behaviour** due to better infrastructure and technology development

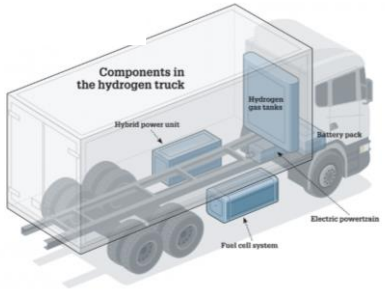


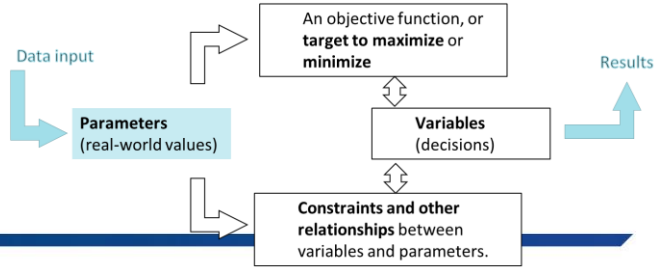
Drivetrain system design tool

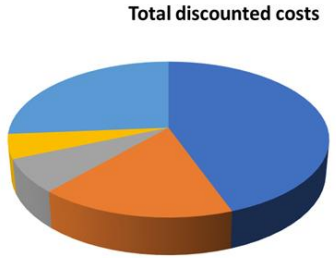
- System concept design – hydrogen/battery hybrid
  (application, infrastructure, outer boundaries)
- Defined routes/time tables and load profiles
  (ship, truck, bus, plane, …)
- Optimise dimensions of system components for lowest total cost of ownership











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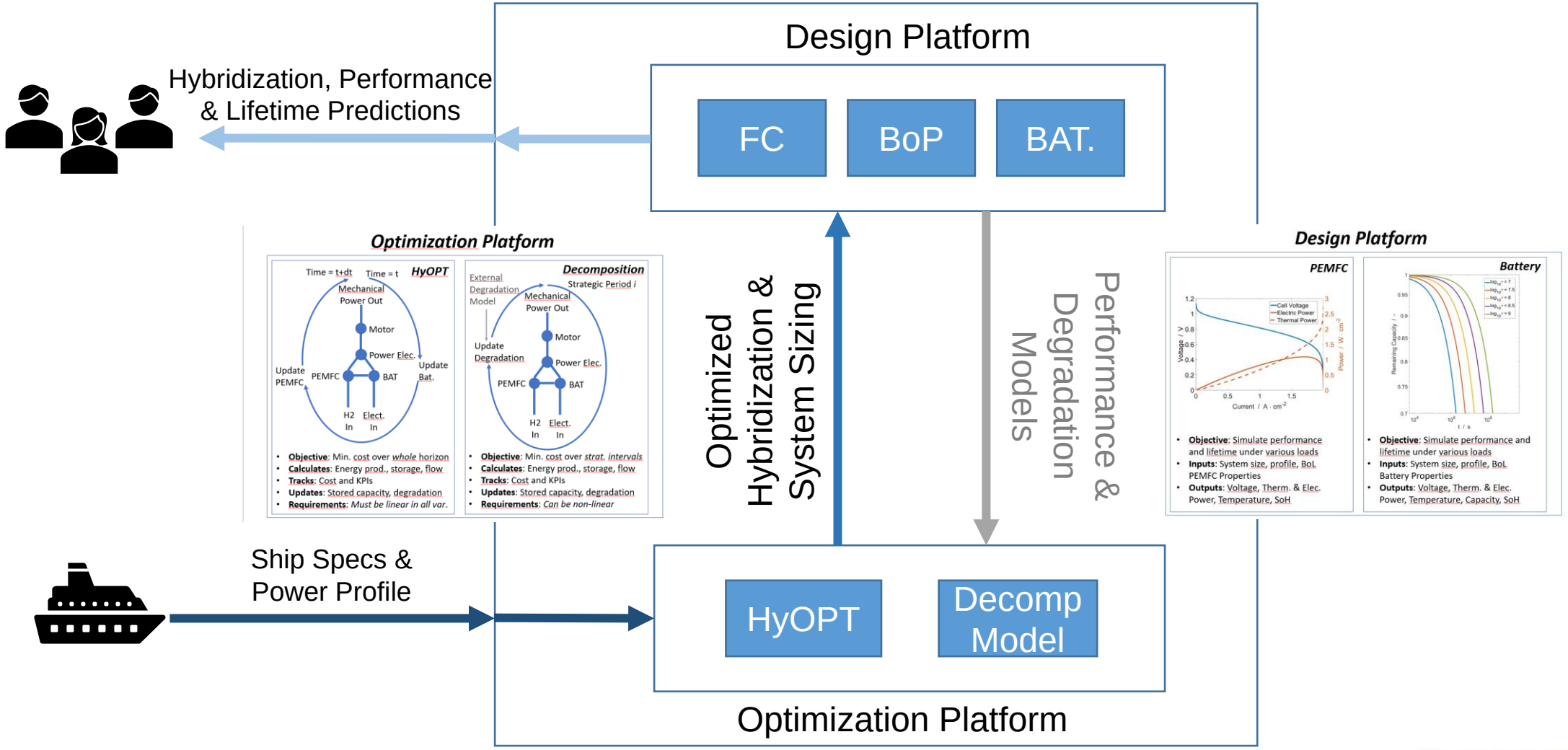
Model for cost-minimal design and operation

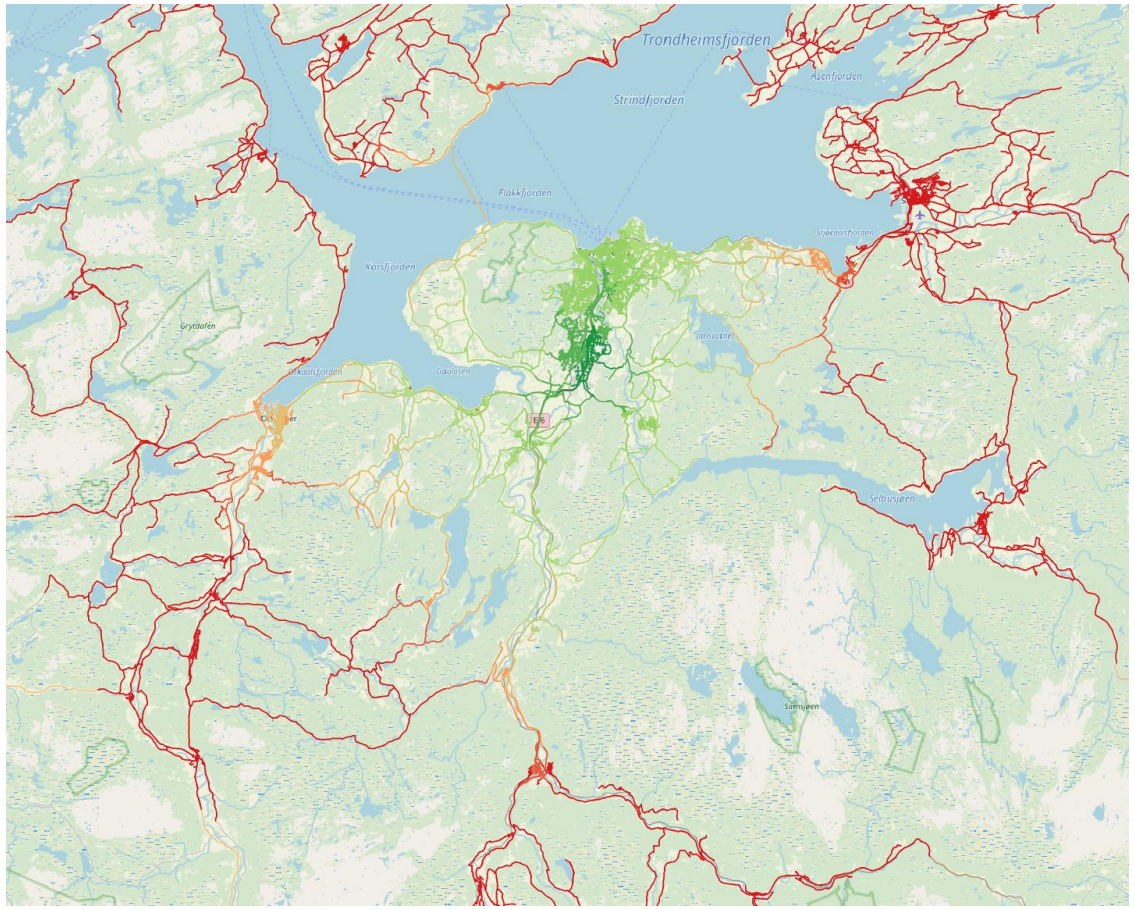


Examples

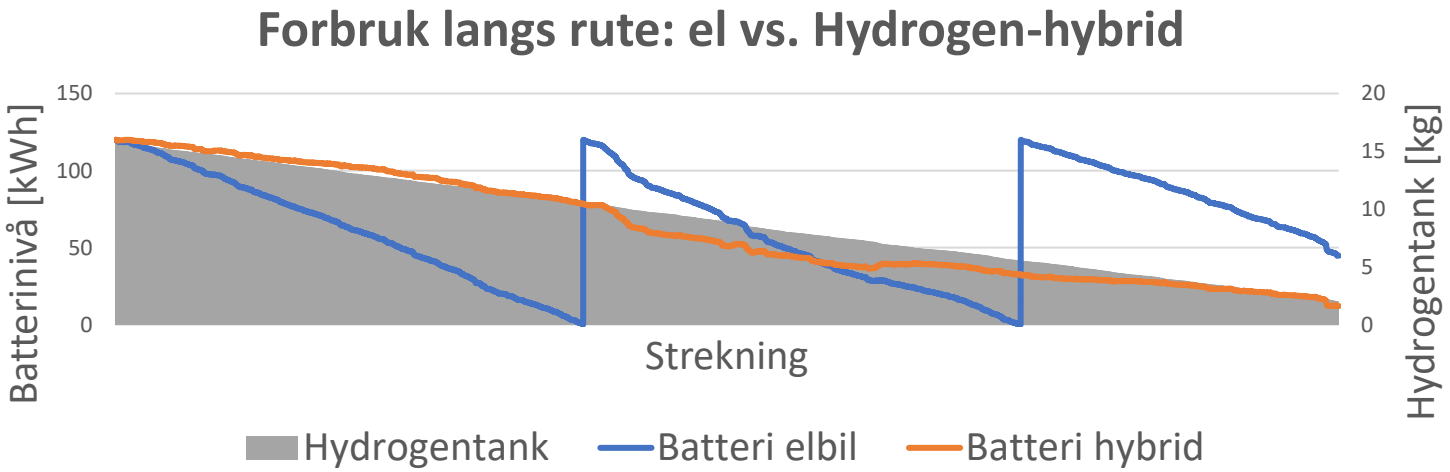
Model for cost-minimal design and operation

- Rekkevidde elbil

www.adressa.no

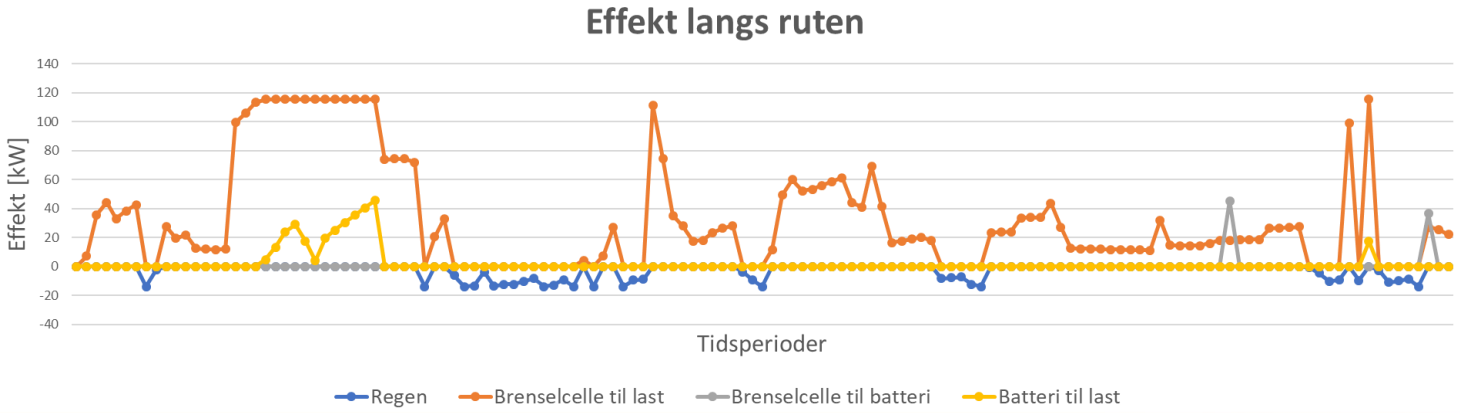


Eksempel: Drivstofforbruk for en rute



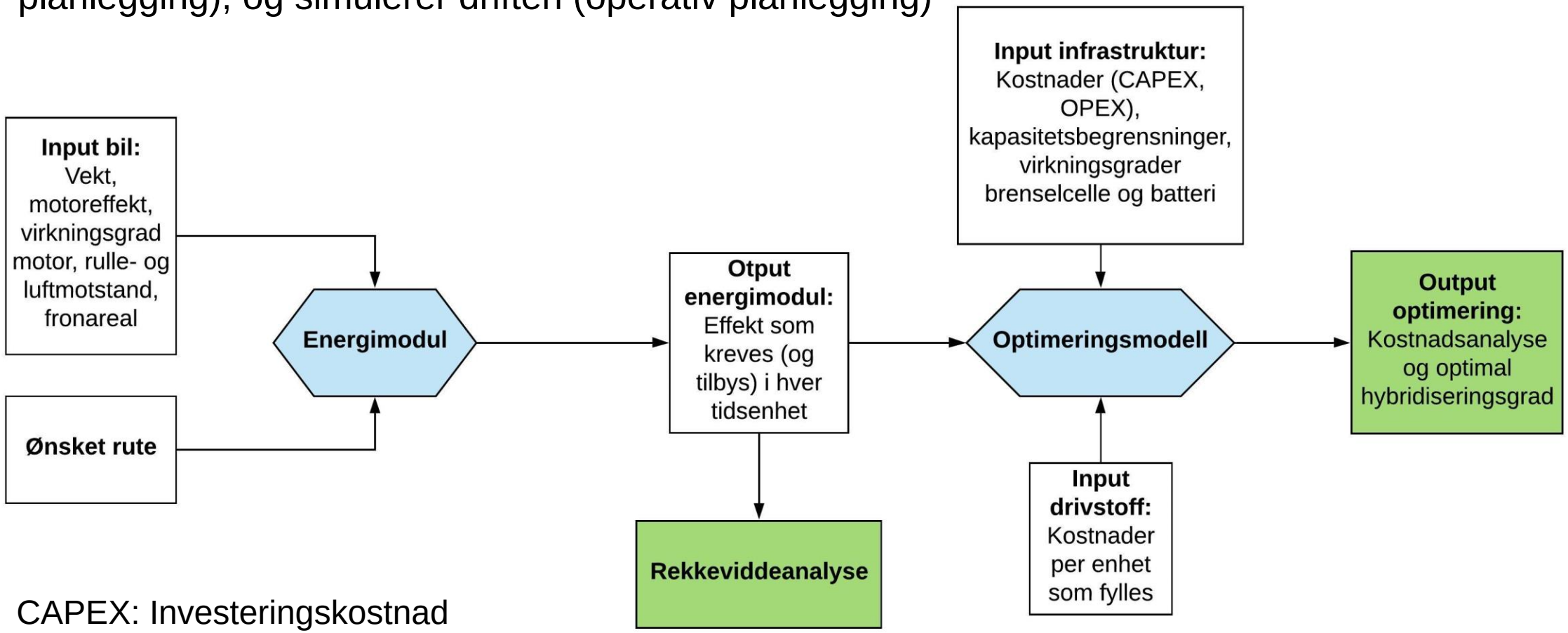
- Elbil vil kreve to ladinger for å fullføre ruten: Betydelig tidsforbruk

Eksempel: Fordeling av effekt ved hydrogenbil

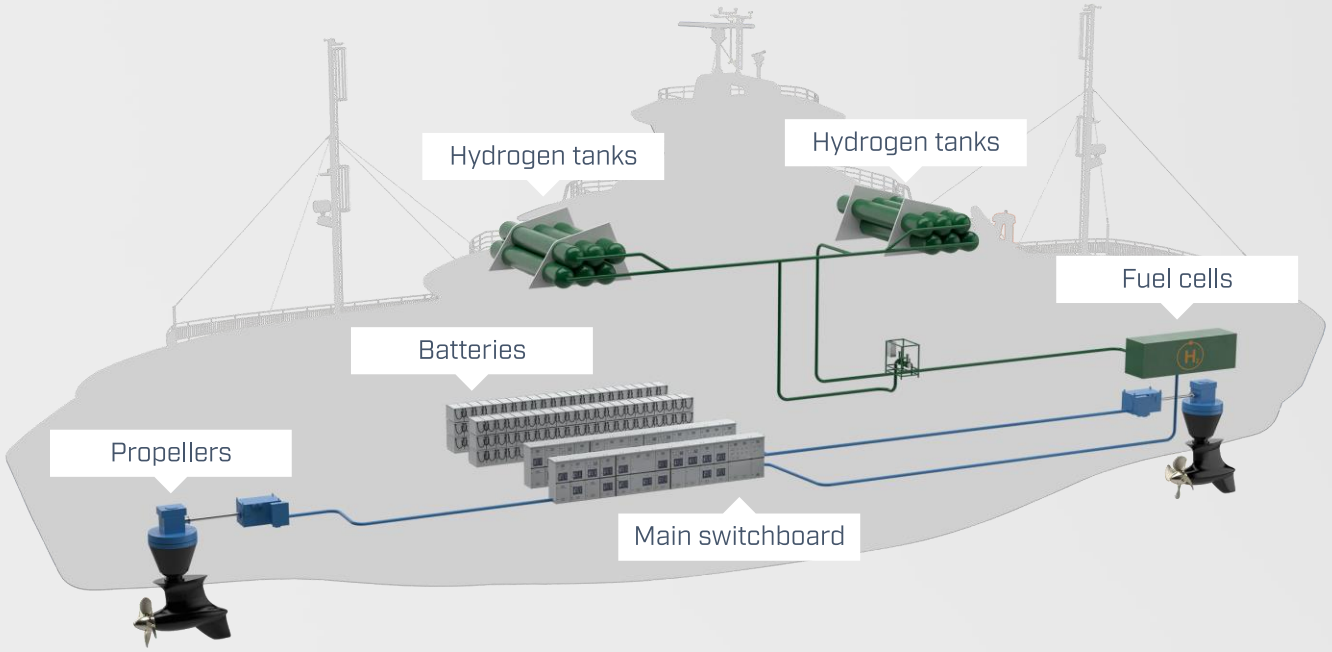


Rammeverk for analyser

- **Kobling av energimodul fra transportmodell og optimeringsmodell**
- Optimeringsmodell dimensjonerer fremdriftssystem/energisystem (strategisk planlegging), og simulerer driften (operativ planlegging)



CAPEX: Investeringskostnad
OPEX: Driftskostnad



Eksempel: HYBRIDskip

Hydrogen powered – Zero emission

Driftsmønster - eksempel

		Operational periods			On-off profiles	
strat per	oper per	duration [t.u.]	tot dur [t.u.]	description	at quay 1	at quay 2
1	1	900	900	pause	TRUE	FALSE
1	2	30	930	klargjøring, frakobling	FALSE	FALSE
1	3	45	975	manøvrering ut fra kai	FALSE	FALSE
1	4	135	1110	akselerasjon	FALSE	FALSE
1	5	3240	4350	overfart	FALSE	FALSE
1	6	120	4470	deakselerasjon	FALSE	FALSE
1	7	60	4530	manøvrering inn til kai	FALSE	FALSE
1	8	30	4560	tilkobling osv	FALSE	FALSE
1	9	300	4860	lossing og lasting	FALSE	TRUE
1	10	540	5400	pause	FALSE	TRUE
1	11	30	5430	klargjøring, frakobling	FALSE	FALSE
1	12	45	5475	manøvrering ut fra kai	FALSE	FALSE
1	13	135	5610	akselerasjon	FALSE	FALSE
1	14	3240	8850	overfart	FALSE	FALSE
1	15	120	8970	deakselerasjon	FALSE	FALSE
1	16	60	9030	manøvrering inn til kai	FALSE	FALSE
1	17	30	9060	tilkobling osv	FALSE	FALSE
1	18	300	9360	lossing og lasting	TRUE	FALSE	FALSE
1	19	9540	18900	pause with H2 fill	TRUE	FALSE	TRUE
1	20	30	18930	klargjøring, frakobling	FALSE	FALSE	FALSE

855 Garten - Storfosna — Operatør: Fosenlinjen AS

Fra Garten			
man-tors	fredag	lørdag	søndag
07.00	07.00	07.00	07.00
08.00	08.00	A08.00	A08.00
09.00	09.00	08.40	08.40
10.00	10.00	09.20	09.20
11.00	11.00		
12.00	12.00	12.00	12.00
13.00	13.00		
14.00	14.00		15.00
14.50	14.50	15.20	
16.15	16.15	16.00	16.00
17.00	17.00		17.00
18.00	18.00		18.00
	19.00	19.00	
20.00		20.00	
21.00	21.00		21.00
A22.00	A22.00	A22.00	A22.00
A22.40	A22.40		

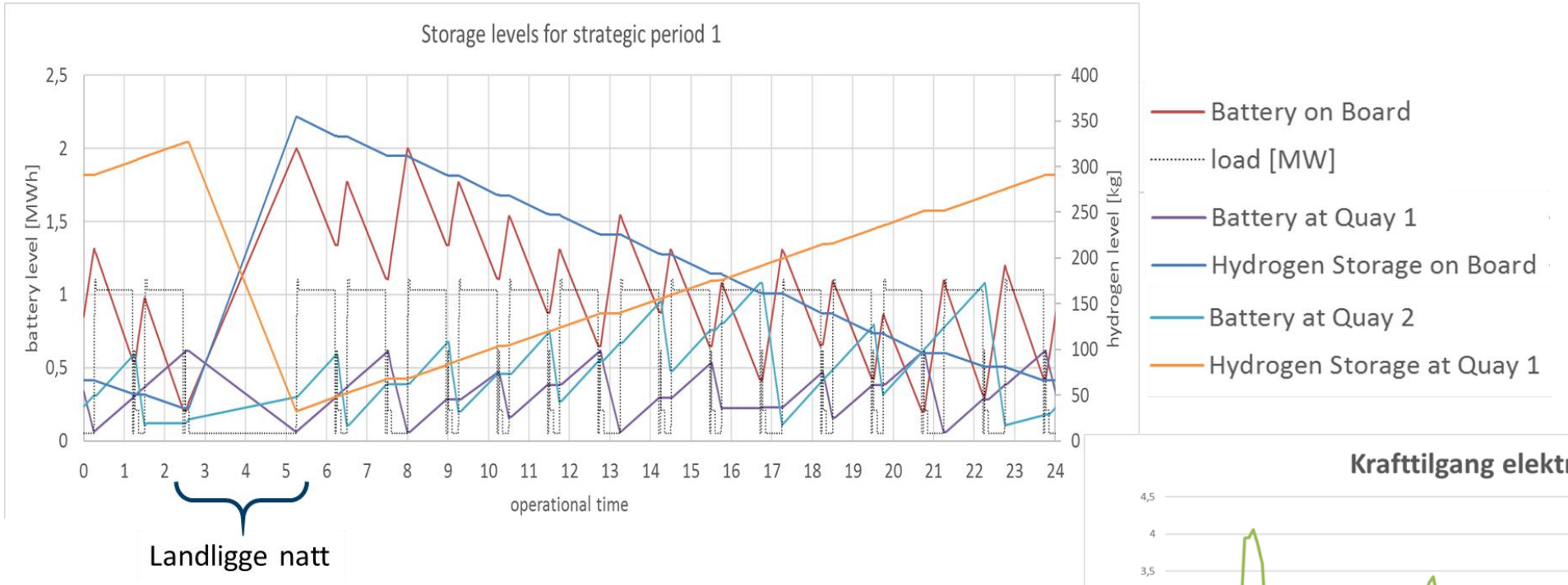
A turen må bestilles 1 time før avgang
C turen må bestilles innen kl 21.00 dagen før
tlf: 995 84 119/481 26 000

Fra Storfosna			
man-tors	fredag	lørdag	søndag
06.25	06.25	C06.40	C06.40
07.25	07.25	A07.30	A07.30
08.30	08.30	A08.20	A08.20
09.30	09.30	09.00	09.00
10.30	10.30		
11.30	11.30	11.40	11.40
12.20	12.20	12.20	12.20
13.30	13.30		
14.20	14.20		
15.30	15.30	15.40	
16.35	16.35		16.30
17.30	17.30		17.30
18.30	18.30	18.30	
19.40	19.30	19.30	
20.30	20.40	A20.30	20.40
A21.30	A21.30		21.30
A22.20	A22.20		

A turen må bestilles 1 time før avgang
C turen må bestilles innen kl 21.00 dagen før
tlf: 995 84 119/481 26 000

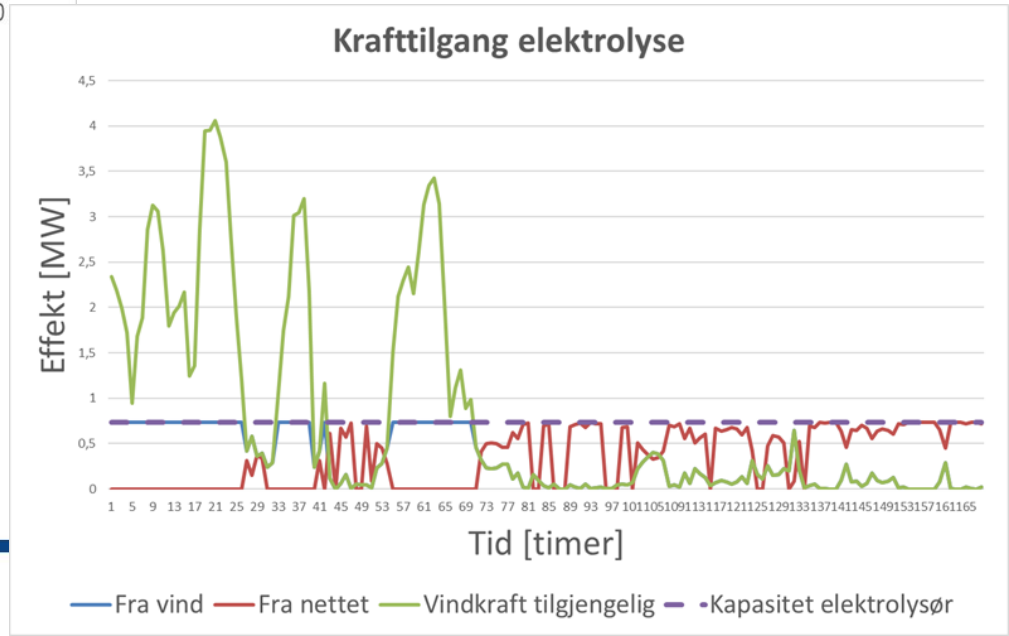
Eksempel: Hybrid 0-utslippsferje

- Driftsprofil batteri og hydrogenlager over døgnets 24 timer



Eksempel:

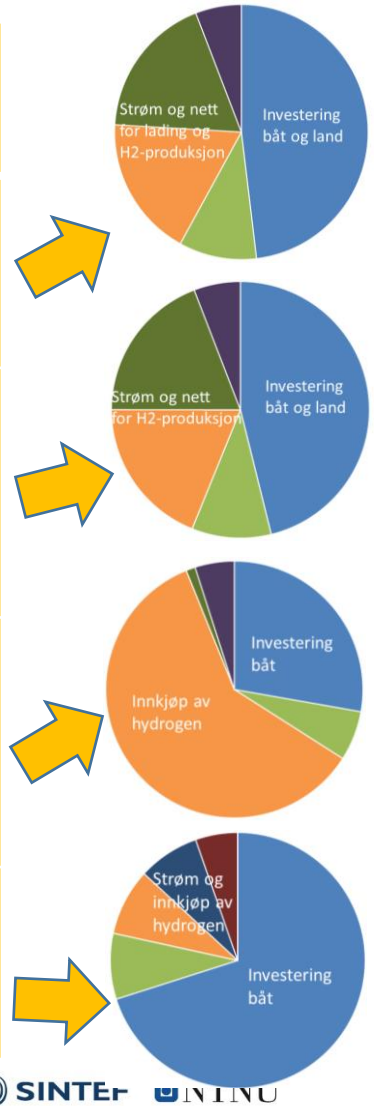
Krafttilgang og forbruk til elektrolyse



Nullutslipps-ferje -> Hva gir lavest kostnad?

- Eksempelsamband

	Batteri-størrelse [kWh]	Brensel-celle, [kW]	Hydrogen -tank, [kg]	Infrastruktur-kostnad [MNOK]	Investering [MNOK]	Driftskostnad per dag, [NOK]	Totalkostnad over 10 år [MNOK]
Hybrid m/lading på begge kaier	200	180	80	1,8	7,6	3200	15,5
H_2 m/egen-produksjon, ingen lading	170	200	95	2,1	8	3600	17, 0
H_2 tilkjørt* ingen lading (nattfylling)	60	260	91	0	6	6000	20,5
Kun batteri, lading på én kai	1000	0	0	3,5	14	1800	18,5



*forutsatt en hydrogenpris på 100 kr/kg

Global Value Chain analysis

Aim: Explore global effects through international trade

Research Questions

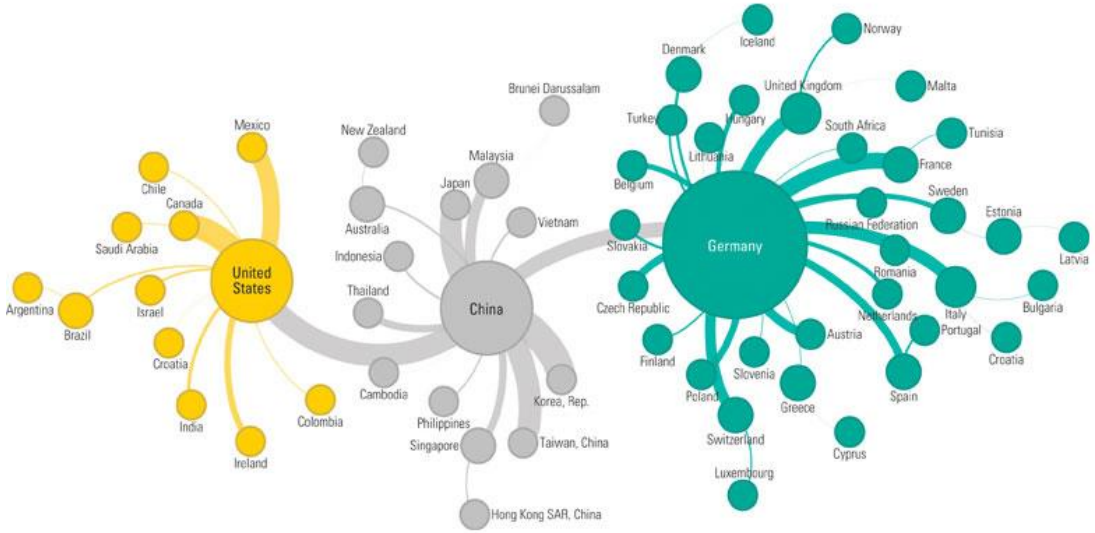
- What are global societal and environmental effects?
- What are the economic effects on upstream value chains?
- Which industries/countries are most effected by a sustainable transition?

Methodology

- Analysis of bilateral trade at the product level
- Combine Input-output (IO) modelling with bilateral trade data

Results

- Environmental impacts by industry and in other countries, e.g. emissions, material use
- Detailed data on raw material extraction and trade of raw and processed materials
- Identification of changing trade patterns
- Distribution of employment opportunities around the world



https://www.worldbank.org/en/topic/trade/publication/book-making-global-value-chains-work-for-development

Micro to macro to global

Aggregation of effects across technologies, industries, countries for a full assessment of complementary and conflicting sustainability effects of technological change.

Examples

- New battery technology
- Hydrogen fuel

References

- Renewable energy technology diffusion
- A global circular economy scenario