Empowering Energy Hubs

Apendices

Master Thesis
Bram Bezooijen
Strategic Product Design
July 2025

TU Delft
ARUP

Appendix A: Project Brief

TU Delft

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME

Complete all fields and indicate which master(s) you are in

Family name	Bezooijen 7514	IDE master(s)	IPD ☐ DfI ☐ SPD ✔
Initials	B	2nd non-IDE master	
Given name	Bram	Individual programme *(date of approval)*	
Student number	4851536	Medisign	☐
		HPM	☐

SUPERVISORY TEAM

Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair	Dr. S. Celik	dept./section	Design, Organisation and Strategy
mentor	M. (Mahshid) Hasankhani	dept./section	Sustainable Design Engineering
2nd mentor	K. Vervuurt		
client:	Arup		
city:	Amsterdam	country:	Netherlands
optional comments			

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in **by the Chair** of the supervisory team

Sign for approval (Chair)

tudelft.protect Jamf Protect CSR Identity

Digitally signed by tudelft.protect Jamf Protect CSR Identity
Date: 2025.01.28 14:12:11 +01'00'

Name: Sine Celik   Date: 27 Jan 2025   Signature: S.C

CHECK ON STUDY PROGRESS

To be filled in **by SSC E&SA** (Shared Service Centre, Education & Student Affairs), after approval of the project brief by the chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total ______ EC

Of which, taking conditional requirements into account, can be part of the exam programme ______ EC

★	**YES**	all 1st year master courses passed
☐	**NO**	missing 1st year courses

Comments:

Sign for approval (SSC E&SA)

L. Boot Digitaal ondertekend door L. Boot Datum: 2025.02.03 10:58:47 +01'00'

Name Lisette Boot Date 3 Feb 2025 Signature

APPROVAL OF BOARD OF EXAMINERS IDE on SUPERVISORY TEAM -> to be checked and filled in by IDE's Board of Examiners

Does the composition of the Supervisory Team comply with regulations?

YES	★	Supervisory Team approved
NO	☐	Supervisory Team not approved

Comments:

Based on study progress, students is ...

★	**ALLOWED** to start the graduation project
☐	**NOT** allowed to start the graduation project

Comments:

Sign for approval (BoEx)

Monique von Morgen Digitally signed by Monique von Morgen Date: 2025.02.04 09:54:16 +01'00'

Name Monique von Morgen Date 4 Feb 2025 Signature

Personal Project Brief – IDE Master Graduation Project

Name student Bram Bezooijen **Student number** 4,851,536

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Project title Designing a Strategic Framework for Mitigating Uncertainties in Hydrogen Based Energy Hubs

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

Hydrogen energy systems are increasingly recognized as a essential part of sustainable energy transitions, particularly within Energy Hubs that integrate renewable energy sources, storage, and distribution technologies. These hubs act as multi-functional energy platforms, balancing supply and demand across electricity, heating, and transport sectors. While hydrogen holds significant potential, its integration is hindered by challenges such as operational inefficiencies, financial uncertainties, and informational gaps. These challenges primarily stem from the complexities of stakeholder collaboration and decision-making, rather than technological limitations, which are expected to diminish over time.

The domain of this project lies at the connection of energy transition strategies, stakeholder collaboration, and hydrogen storage integration. Key stakeholders include municipal authorities, energy providers, technology developers, community representatives, and investors. Their interests vary, ranging from operational feasibility and economic viability to day-to-day operational practices, regulatory compliance, and public acceptance. The success of hydrogen-based Energy Hubs depends on designing localized systems that can achieve their own balance while addressing stakeholder-specific challenges.

Opportunities within this domain include developing a scenario-based strategic tool that aligns stakeholder interests, mitigates risks, and enhances decision-making processes. Scenarios will allow for a deeper understanding of uncertainties and enable the design of tools tailored to specific operational and financial contexts, particularly within the Netherlands. However, the complexity of balancing stakeholder needs, coupled with evolving market and regulatory conditions, presents significant limitations.

By focusing on localized scenarios and stakeholder dynamics, this project aims to create actionable solutions for integrating hydrogen systems into Energy Hubs effectively.

➔ *space available for images / figures on next page*

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

Hydrogen-based Energy Hubs face barriers to adoption due to a lack of strategic tools to manage multi-stakeholder collaboration and decision-making under uncertainty. While technological advancements such as power-to-gas systems are expected to mature over time, the key challenges lie in addressing financial and operational risks and understanding the dynamics of day-to-day operational interactions among stakeholders. Localized systems must find ways to achieve their own balance within specific regulatory and market contexts, such as those in the Netherlands.

Current approaches often fail to provide comprehensive solutions that integrate stakeholder priorities with technical feasibility, economic sustainability, and practical operational considerations. Furthermore, the lack of scenario-based strategies to explore uncertainties and align stakeholder goals limits the effectiveness of existing tools.

This project aims to bridge this gap by designing a strategic tool that leverages scenario-based approaches to align stakeholder collaboration with the efficient integration of hydrogen systems into Energy Hubs. By addressing uncertainties through tailored scenarios, the framework will provide actionable solutions to scale adoption, support localized balancing, and promote energy transition goals.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Develop potential scenarios for implementing Energy Hubs that effectively address key identified uncertainties and challenges, taking a holistic approach that incorporates all stakeholder perspectives and provides actionable insights to enhance the integration and efficiency of energy systems.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

The project will follow a structured approach, combining research and design methodologies to develop a scenario-based strategic tool. The initial phase involves a literature review to acquire knowledge on hydrogen technologies, Energy Hubs, and existing strategic tools, with a focus on identifying practical and stakeholder-relevant gaps rather than starting from scratch.Next, stakeholder interviews will be conducted, leveraging Arup' s network of energy providers, municipal authorities, and investors, to gather insights into operational and financial challenges, day-to-day interactions, and the local feasibility of hydrogen integration, particularly in the context of the Netherlands. The data will be analyzed thematically to identify key challenges, uncertainties, and opportunities specific to stakeholder needs.
The framework development phase will adopt design methodologies such as scenario planning and systems thinking to explore uncertainties and create tailored solutions. Scenarios will be used to model stakeholder-specific dynamics and align priorities, ensuring the framework addresses practical and localized challenges.
Finally, the framework will be validated through hypothetical case studies and expert feedback sessions, focusing on ensuring its practicality, scalability, and alignment with stakeholder requirements while facilitating efficient decision-making and collaboration in energy transition projects.

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	16 Jan 2025
Mid-term evaluation	
Green light meeting	
Graduation ceremony	

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

The obvious main reason that i want to start this program is that im exited to finish my masters degree en being able to start working and applying my skills and knowledge to real life projects. I wish to develop my organisation skills, as this project requires me to plan everyting myself and give myself deadlines, this is a topic where I still have lots of room for improvement. I am also exited about learning more about strategy/framework development. Developping a framework with the correct methodologies and research is something that I have not done within my studies but its something that I think is very usefull for me in the future.

Last of all im exited to learn more about the topic of Hydrogen, Sustainability is a very important theme for me and its where I want to focus on in my carreer later. So all the knowledge that I aquire within this project is usefull for the future.

Within projects I like to be the person that sees the bigger picture and can make connections that have a positive impact that people would not make that fast. I hope in the end that I am able to see the bigger picture withing the topic of my research.

Appendix B: Interview guidelines and questions

1. **Onderzoekscontext**
   De reden dat ik contact opneem, is mijn afstudeeronderzoek naar energiehubs, met speciale aandacht voor de combinatie van elektrolyser en batterijopslag. Gezien de expertise van **{naam bedrijf}** in de energiesector ben ik benieuwd naar uw visie op de uitdagingen, kansen en onzekerheden die komen kijken bij het realiseren van energiehubs.

2. Mijn onderzoek richt zich op de implementatie-onzekerheden rondom energiehubs, en hoe binnen die onzekerheden strategische keuzes gemaakt kunnen worden. Op basis van literatuuronderzoek heb ik een aantal hoofdthema's opgesteld die ik graag met u zou willen bespreken.

1. Introductie

1. Wat is de rol van **{naam bedrijf}** bij het ontwikkelen, beheren of faciliteren van energiehubs?
2. Met welk type energiehubs heeft **{naam bedrijf}** ervaring, en in welke context?
3. Welke doelen ziet **{naam bedrijf}** voor energiehubs (bijvoorbeeld netontlasting, CO2-reductie, kostenoptimalisatie, flexibiliteit)?
4. Welke algemene onzekerheden of risico's ervaart **{naam bedrijf}** bij de implementatie van energiehubs?

2. Operatie en planning

1. Hoe wordt bepaald wanneer flexibiliteit (bijvoorbeeld opslag, electrolyser) wordt ingezet versus teruglevering naar het net?
2. Welke technieken of systemen gebruikt **{naam bedrijf}** om vraag en aanbod te voorspellen, en hoe betrouwbaar zijn deze in de praktijk?
3. Hoe wordt samenwerking tussen meerdere partijen georganiseerd binnen een energiehub, bijvoorbeeld over eigenaarschap, onderhoud, verdeling van kosten en baten?
4. Welke rol speelt de keuze van eigenaar/beheerder in de dagelijkse operationele beslissingen?
5. Welke uitdagingen ziet **{naam bedrijf}** voor de lange termijn, zoals uitbreiding of integratie van nieuwe technologieën?
6. Welke risico's ziet u en welke strategieën worden gehanteerd om deze te beperken?

3. Financiering en investeringen

3. Hoe gaat **{naam bedrijf}** om met de financiering van energiehubs, en welke factoren bepalen de haalbaarheid van een businesscase?
4. Wat zijn volgens u de grootste onzekerheden bij het inschatten van de terugverdientijd?
5. In hoeverre speelt schaalvergroting een rol bij het rendabel maken van een energiehub?

6. Welke invloed hebben veranderende beleidskaders en subsidieregelingen op investeringsbeslissingen?

4. Netwerkaansluiting en capaciteit

1. Hoe kijkt **{naam bedrijf}** aan tegen (gedeeltelijk) off-grid energiehubs, bijvoorbeeld op een bedrijventerrein?
2. Welke technische of juridische aspecten spelen mee bij de keuze voor een off-grid of semi-off-grid hub?
3. Welke meerwaarde ziet u voor netbeheerders of andere partijen door het realiseren van energiehubs?
4. Hoe verwacht **{naam bedrijf}** dat de groei van energiehubs het toekomstige net zal beïnvloeden?
5. Hoe vindt de afstemming plaats met andere stakeholders om een goede balans te vinden tussen netversterking en lokale flexibiliteit?

5. Tarieven en regulering

1. Hoe beoordeelt **{naam bedrijf}** de invloed van huidige tariefstructuren op de businesscase van energiehubs?
2. Welke kansen en risico's ziet u in dynamische tarieven of alternatieve regelingen zoals flexcontracten?
3. Welke rol speelt regelgeving rondom waterstof (certificering, garanties van oorsprong, bijmenging) op de opschaling?
4. In hoeverre verschillen de reguleringen per land of regio, en wat betekent dat voor locatiekeuzes?
5. Zijn er volgens u voldoende prikkels vanuit beleid om batterijopslag en waterstofproductie grootschalig op te zetten?

6. Afsluitend

1. Welke rol ziet **{naam bedrijf}** voor zichzelf in de verdere ontwikkeling van energiehubs?
2. Denkt u dat een electrolyser-energiehub concept schaalbaar en waardevol is?
3. Zijn er volgens u nog andere factoren of uitdagingen die tot nu toe onderbelicht blijven maar belangrijk zijn voor succes?

Bedankt voor uw tijd en bereidheid om hierover in gesprek te gaan.

Appendix C: Interview Insights

Found Uncertainties through interviews

#	Uncertainty	What exactly is unclear?	Why it exists?	Impact on energy hub design & business case	Uncertainty direction
1	**Legal & contractual framework**	**Group-connection contract:** parameters (capacity, duration, penalties, grid-operator curtailment rights, tariff structure). **Alternative Transport Right:** how often and how deep can capacity be curtailed?	Group contracts do not yet exist in Dutch legislation; DSO and regulator are still drafting. ATR is only a interim rule, written conservatively to protect system security	**Sizing of assets:** developers don't know how large a hub connection they will actually get. **Revenue model:** can a hub earn from flexibility if the DSO can cut 15% of capacity at short notice? **Financial risk:** lenders dislike open-ended technical or tariff clauses.	**Tight & risk-averse (today):** small guaranteed capacity, high curtailment, hubs need oversized storage and earn little. **Looser & market-oriented:** clearer caps on curtailment, sliding-scale tariffs, long term visibility = easier funding, smaller batteries.
2	**DSO risk appetite**	How far will DSOs/TSOs relax traditional safety-margins and hand over real-time control to hub operators?	Dutch grids were planned for **"fit and forget"**; cultural focus on 99% uptime. Legal liability if blackouts occur.	If margins stay wide, the "pizza" the hub receives shrinks → fewer participants see value; more capex in on site generation required.	Progressive DSOs may gradually trust certified EMSs & dynamic congestion management, letting hubs use higher coincident capacity.
3	**Intra-hub allocation and governance**	What allocations keys, voting rules and exit clauses will participants accept? (3 layer model: baseline right – internal trade – external top up)	Participants differ in size, load profiles, capex budgets and ESG aims; there is no Dutch template yet.	Poorly designed rules create free-rider risks, litigation or stranded assets. Capex decisions hinge on the agreed rights.	Early hubs will prototype variants (pro-rate, pay-as-you-grow, auction of unused kW) Industry associations

					may converge on a standard.
4	**Wholesale & retail price signals**	Accuracy of long-term power-price forecasts; evolution of imbalances prices; remuneration of flexible capacity	EU power market reform is ongoing: Dutch carbon taxes, RES subsidies and capacity, mechanism debates continue.	Hard to prove ROI on battery/P2X if price spreads could collapse (or explode)	High volatility + scarcity pricing → storage pays back quickly. Low spreads due to mass RES + grid expansion → batteries marginal, H2 moves to off-stie production.
5	**CAPEX & technology cost curves**	Future costs/availability of batteries, electrolysers, smart grid hardware	Supply-chain geopolitics, raw-material prices, learning curves,	Determines which flexibility mix each scenario can afford and the hubs carbon/energy efficiency	Rapid cost declines, open multicommodity hubs; cost spikes favour minimal hardware hubs relying on contractual swapping only.
6	**Multi-commodity integration**	Timing of a national hydrogen backbone; permissibility of private heat networks			

Key topics from interview:

1. Alliander, Liander and Firan – Institutional Roles

What was said:

Jidde outlined the structure of Alliander as the holding company. Liander is the regulated DSO responsible for electricity and gas distribution in several Dutch provinces. Firan is a more entrepreneurial sister company under Alliander, designed to work on innovative infrastructure projects that DSOs aren't legally allowed to engage in—like heat grids, hydrogen infrastructure, and decentralized energy systems.

Why it matters:

Firan occupies a niche that allows it to bridge innovation and regulation, making it an important enabler of experimental approaches like energy hubs.

2. Closed Distribution Systems (CDS) vs. Energy Hubs

What was said:
CDS are private networks where multiple users connect without DSO involvement. In contrast, energy hubs operate on shared capacity within the DSO's grid, allowing coordinated use without full independence. Jidde stressed that CDS imply full legal and technical separation from the public grid, whereas hubs offer flexibility while maintaining grid fallback.

Why it matters:
Energy hubs are more inclusive and pragmatic for current Dutch regulatory constraints. CDS remains a conceptual influence but is not scalable under current rules.

3. Congestion as a Trigger for Hubs

What was said:
Due to grid congestion, companies can no longer get new or expanded contracts. This has led to the emergence of energy hubs as a workaround, enabling grouped usage of grid capacity. Jidde emphasized this as both a necessity and an opportunity for systemic improvement.

Why it matters:
Congestion is both a constraint and a catalyst. Hubs may become essential not just temporarily but structurally in the future energy system.

4. Group Contracts & Legal Bottlenecks

What was said:
There are no formal legal group contracts yet, which are essential for operating energy hubs. Jidde explained this as a major blocker. Current workarounds like ATR (Alternative Transport Rights) are temporary and complex.

Why it matters:
The lack of legal instruments is one of the biggest barriers to widespread implementation of hubs. Firan is actively engaged in pilot projects to inform how such contracts should be designed.

5. Risk Aversion of DSOs

What was said:
Liander and other DSOs are very risk-averse due to their historical responsibility for uptime and safety. This leads to conservative contracts and operational limitations that don't reflect the full potential of shared, real-time flexibility.

Why it matters:
Without a shift in DSO culture, hubs will be over-dimensioned or underused. Building trust between DSOs and energy users is critical.

6. Internal Allocation Within Hubs

What was said:
Jidde described a "three-layer model":

- Base allocation (your guaranteed slice
- Internal exchange (borrowing from others
- External fallback (drawing from the main grid)This requires detailed agreements and trust between participants.

Why it matters:
Fair and functional internal governance is crucial for hub viability, especially with participants of different sizes and load profiles.

7. Investment Uncertainty & Business Models

What was said:
Companies hesitate to invest in hubs due to cost uncertainty and unclear return on investment. Technologies like batteries or hydrogen systems may be necessary but expensive.

Why it matters:
High CAPEX with unclear payback periods limits willingness to initiate hubs. Tooling and shared modelling (such as what Firan offers) can reduce this friction.

8. Firan's Role and Tools

What was said:
Firan acts in between the market and the DSO. It helps design, model, and test new solutions without distorting the market. It has developed tools such as energy hub modelling software and acts as a technical and strategic advisor.

Why it matters:
Firan is uniquely positioned to help develop scalable energy hub frameworks by combining infrastructure knowledge with market-neutral innovation.

9. Future Outlook: Flexibility and Multi-Commodity Hubs

What was said:
Jidde envisions future hubs not just for electricity, but also integrating heat and hydrogen. Temporary or flexible hub participation will become more common. He foresees new trading dynamics where surplus electricity can be converted and stored differently.

Why it matters:
Multi-commodity integration will increase system flexibility and economic value—but it depends on regulation and technology catching up.

10. Who Takes Initiative?

What was said:
Energy hubs currently depend on private or public stakeholders (e.g. companies or municipalities) to initiate. DSOs cannot steer or promote hubs actively due to market neutrality laws, although they do have relevant data.

Why it matters:
A gap exists between where the problem (congestion) is known and where the initiative arises. Firan and others are exploring how to bridge this without violating rules.

Appendix C: Interview Insights Clustering

Appendix D: Cross case comparison table energy hubs

Cross case comparison 5 energy hubs

Criteria	Case 1	Case 2	Case 3	Case 4	Case 5
CO_2 reduction	High (Significant Co2 from diesel substitution)	Moderate (less CO_2 emissions from less energy curtailment)	Low (Minimal reduction from less diesel)	High (high extra solar energy, avoided CO_2)	High (replacement of grey hydrogen with green)
Generated renewable electricity	Moderate	Low	Low	High	High
Financial impact	Very positive (positive prosperity effect in 10 years, lower energy costs)	Positive (positive prosperity in comparison to reference)	Positive (No large investments needed)	Negative (negative prosperity effect in 10 years trough high investments in new solar and storage)	Negative (negative prosperity effect in 10 years through high investments in new solar and storage)
Stakeholder collaboration complexity	High (collaboration between 20 companies for shared infrastructure)	Low (Existing infrastructure and 4 companies)	High (collaboration between 19 companies for shared infrastructure)	Moderate (4 companies but large project)	Moderate (1 dominant party but with new parties for generation)
Dependency on grid	Average (peak capacity lowers but more interaction time with grid)	Decreasing (local exchange and less curtailment)	Average (peak offtake decreases slightly, more shared assets)	Decreasing during peaks (collective control, substantial feed in is limited)	Relatively high (back up and peak moments, lower than reference)
Grid connection (Feed-in/Offtake	Both	Offtake	Both	Offtake	Offtake
Spatial impact	Negative	No impact	No impact	No impact	Negative

Appendix D: Arup projects analysis

Project 1:

Risico Domein	Observaties	Aanbevelingen
Organisatie en Governance	Het bedrijf hergroepeert meer dan honderdvijftig locaties in een nieuw netwerkmodel, maar rollen en beslisrechten zijn nog niet duidelijk vastgelegd. • De huidige rapportering over risico's gebeurt onregelmatig.	• Leg vóór begin 2025 een volledige "Responsibility-Accountability-Consulted-Informed"tabel vast zodat elke locatie weet wie verantwoordelijk is. • Stel één centraal risicoteam in dat maandelijks rapporteert aan de directie.
Contracten en interface beheer	Veel bestaande contracten zijn zwaar bewerkt, waardoor garanties en aansprakelijkheid niet controleerbaar zijn. • Oude installaties moeten worden gekoppeld aan nieuwe uitbreidingen, wat leidt tot "grijze zones" in verantwoordelijkheid.	• Introduceer een uniform contractmodel met dezelfde service-niveaus voor elke locatie. • Maak per locatie een actueel overzicht van alle raakvlakken tussen oude en nieuwe installaties.
Vergunningen en compliance	Bij vier locaties is bodemverontreiniging vastgesteld; de saneringskosten zijn nog niet opgenomen in de projectplanning. • Voor sommige uitbreidingen is de milieuvergunning verjaard.	Laat vóór eind 2025 voor alle locaties een bodemonderzoek uitvoeren en reserveer geld voor sanering. • Gebruik een digitale vergunningenkalender met duidelijke mijlpalen en verantwoordelijken.
Technologie maturiteit	Een deel van de sorteerlijnen draait al tientallen jaren; de onderdelen zijn aan het einde van hun levensduur. • De beschikbaarheid van de installaties is gemiddeld negenenzeventig procent, wat lager is dan het branchegemiddelde.	Laat alle kritieke machines inspecteren en stel een verjongingsplan op. • Reserveer vijftien procent extra investeringsgeld voor onverwachte technische problemen met oude apparatuur.
Beschikbaarheid en KPIs	• Slechts achteraf-indicatoren worden gemeten; er zijn geen voorspellende signalen zoals mean-time-between-failur	• Zorg dat het nieuwe onderhoudssysteem bij oplevering in 2026 standaard voorspellende indicatoren toont. • Koppel een bonus-malus-regeling aan locaties die langer dan vijfentachtig procent beschikbaar zijn.

	es. • Beschikbaarheid varieert sterk per locatie.	
Aanvoer van grondstoffen of inputzekerheid	De aanvoer varieert in samenstelling; dat beïnvloedt de recycle-efficiëntie. • Er is geen langdurige kwaliteitsgarantie met de grootste klanten	Sluit meerjarige contracten waarin maximaal toegestane vervuiling en minimum calorische waarde zijn vastgelegd.
Afzet en markttoegang	• Prijzen van metaal- en glasrecyclaten schommelen sterk. • Ruim een derde van het afval gaat alsnog naar verbranding.	Sluit langjarige koop-overeenkomsten met vaste minimum-volumes. • Zoek nieuwe afzetmarkten, bijvoorbeeld in de bouwsector.
Milieu en Maatschappij	De doelstelling om in 2030 vijfenzeventig procent te recyclen is "zacht" geformuleerd. • Uitstoot van schakels buiten de eigen poort (Scope drie) is nog niet in kaart gebracht.	Maak een jaarlijks stappenplan om de vijfenzeventig procent te halen. • Laat uiterlijk 2025 een onafhankelijke beoordeling uitvoeren van alle uitstoot in de hele keten.
Nutvoorzieningen, ruimtebeslag en logistiek	Op één locatie wordt al meer afval verwerkt dan de vergunning toelaat. • De groei van elektrisch vrachtverkeer vraagt om extra netcapaciteit.	• Vraag tijdig een verruiming van de verwerkings-vergunning aan. • Plaats proefprojecten met batterijopslag om piekbelasting te dempen.
Gezondheid, veiligheid en milieu incidenten	Brandrisico is hoog, maar er worden nauwelijks "bijna-ongelukken" gemeld. • Trends voor verloren-werkdagen dalen, maar pro-actieve data ontbreekt.	• Integreer een systeem waarin elke bijna-aanrijding of bijna-brand wordt vastgelegd. • Voer elk kwartaal een gesimuleerde brandoefening uit.
Financien investeringen en bedrijfskosten	• Er is twintig miljoen euro gereserveerd voor de transitie, maar eventuele overschrijdingen zijn niet afgedekt. • Het onderhoudsbudget schommelt tussen drie en vijf procent van de omzet.	• Houd een aparte onderhoudsreserve aan, zodat investeringen niet worden uitgesteld. • Koppel een besparingsbonus aan locaties die langer dan vijfentachtig procent beschikbaar zijn.

Project 2

Risico Domein	Observaties	Aanbevelingen
Organisatie en Governance	• Er is een samenwerkingsverband tussen drie aandeelhouders, maar het formele handboek voor besluitvorming is nog niet af. • De partners hebben weinig gedeelde ervaring met dit type fabriek.	• Rond vóór het uiteindelijke investeringsbesluit het handboek met procedures en escalatielijnen af. • Geef het projectmanagementbureau expliciet de bevoegdheid om elke ontwerpwijziging te toetsen aan kosten, planning en risico's.
Contracten en interface beheer	De bouw is opgedeeld in elf afzonderlijke pakketten zonder één overkoepelend bouwcontract. • Het contract met de afvalleveranciers is nog niet getekend.	• Sluit één integratiecontract dat precies benoemt wie eindverantwoordelijk is voor het samenbrengen van alle bouwpakketten. • Leg in het contract met de afvalleveranciers vast hoe kwaliteit, volume en aansprakelijkheid worden gehandhaafd.
Vergunningen en compliance	De milieuvergunning is verleend, maar de bouwvergunning moet nog worden aangevraagd. • In de huidige milieuvergunning is nog geen klimaatbestendigheidstoets opgenomen, wat sinds de nieuwe Europese taxonomie verplicht is.	• Start onmiddellijk de bouwvergunningprocedure om vertraging te voorkomen. • Voer uiterlijk binnen zes maanden een klimaatrisico- en kwetsbaarheidsanalyse uit en verwerk de uitkomst in alle vergunningen.
Technologie maturiteit	De kerntechnologie (afvalvergassing en gasreiniging) is nog nooit op deze schaal toegepast. • Betrouwbaarheidsstudies zijn gebaseerd op proeffabrieken met een lager rendement.	Plan een geleidelijke opstart waarbij de fabriek in vier jaar tijd van vijftig naar honderd procent capaciteit gaat. • Plaats een kleine testinstallatie naast de hoofdinstallatie om kinderziektes vroegtijdig te ondervangen. • Houd twintig procent technisch reservebudget aan voor onverwachte problemen.
Beschikbaarheid en KPIs	• Het financiële model rekent op meer dan negentig procent beschikbaarheid, maar de eigen studie voorspelt achtentachtig procent. • Er zijn geen prestatieafspraken vastgelegd met de toekomstige onderhoudspartij.	• Herbereken het financiële model met een basislijn van tachtig procent beschikbaarheid. • Neem in het onderhoudscontract een bonus- en boeteregeling op voor het halen van tussenstappen in de opstartcurve.

Aanvoer van grondstoffen of inputzekerheid	Vier regionale afvalbedrijven vormen samen met de fabriek een tijdelijk samenwerkingsverband, maar het contract is nog niet openbaar. • Zesentig-vijf procent van het afval moet biogeen zijn om aan de Europese eisen te voldoen.	Veranker in het contract een boeteregeling voor lagere biogene inhoud. • Leg een duidelijke uittredclausule vast voor het geval een partner niet kan leveren.
Afzet en markttoegang	• Er zijn pas intentieverklaringen met potentiële afnemers; geen bindende contracten. • Het waterstofverbruik in de fabriek is nog grotendeels "grijs", dus de methanol krijgt geen hoogste duurzaamheidslabel.	• Zorg vóór het investeringsbesluit dat minstens zestig procent van de productie ondertekende koopcontracten heeft. • Leg stapsgewijs hogere eisen aan de duurzaamheidskwaliteit van aangekochte waterstof vast.
Milieu en Maatschappij	De levenscyclusanalyse is gebaseerd op oudere Europese richtlijnen en moet worden geüpdatet. • Certificering van duurzaamheid is nog niet aangevraagd.	• Werk de levenscyclusanalyse bij op de nieuwste regelgeving en laat vooraf een audit uitvoeren. • Plan de certificeringsaudit voordat de fabriek opstart.
Nutvoorzieningen, ruimtebeslag en logistiek	De fabriek gebruikt veel leidingwater in een regio die regelmatig met droogte te maken heeft. • De aansluiting op het elektriciteitsnet is wel reeds bevestigd.	• Voer een programma in voor hergebruik van water en verklein het verbruik met ten minste tien procent. • Leg uiterlijk in 2028 een volledig groene stroomlevering vast.
Gezondheid, veiligheid en milieu incidenten	Het huidige kader voor veiligheid is vooral gericht op achteraf meten. • Er zijn scenario's met giftige gassen, maar die zijn nog niet geoefend.	Introduceer leidende indicatoren zoals observaties en analyses van het laatste-minuut-risico. • Organiseer vóór de inbedrijfstelling een grote oefening rond een waterstoflek.
Financien investeringen en bedrijfskosten	• Het investeringsbudget is ruim zevenhonderd-negenenvijftig miljoen euro; de gereserveerde marge voor tegenvallers is slechts zeven procent. • Bijna de helft van de jaarlijkse kosten bestaat uit de aankoop van waterstof.	Verhoog de reservering voor tegenvallers naar minimaal vijftien procent. • Maak de prijsformule voor waterstof afhankelijk van de elektriciteitsprijs, maar leg ook een maximumprijs vast.

Project 3:

Risico Domein	Observaties	Aanbevelingen
Organisatie en Governance	Er is onduidelijkheid over wie het eiland in de eerste fase beheert en wie in de latere uitbreidfases. • Publieke en private organisaties volgen verschillende besluitlijnen.	• Teken één gezamenlijk bestuursdocument waarin bevoegdheden van overheid, netbeheerders en commerciële partijen voor alle bouwfasen zijn vastgelegd. • Stel een stuurgroep in met vaste vertegenwoordigers van alle netbeheerders en ministeries.
Contracten en interface beheer	• Voor het eiland worden civiele werken, hoog-spanningskabels en waterstofinstallaties apart aanbesteed, maar niemand heeft het totaalontwerp in handen.	Wijs één partij aan als "ontwerp-bouw-en-beheer-integrator" die verantwoordelijk is voor het totaalontwerp. • Maak een gezamenlijke pot geld van drie procent van het bouwbudget waarmee eventuele interface-problemen snel kunnen worden opgelost.
Vergunningen en compliance	Het eiland heeft goedkeuring nodig van meerdere kuststaten; procedures lopen door elkaar. • De planning van de windparken en van de hoog-spanningsverbindingen hangt direct af van deze goedkeuringen.	• Maak samen met alle betrokken autoriteiten één tijdlijn waarin alle vergunningstappen per land zijn vastgelegd. • Vraag alvast een voorlopige vergunning aan voor het opspuiten van de eerste caissons, zodat de bouw niet stilvalt.
Technologie maturiteit	• Het caisson-eiland in combinatie met een meer-aansluitende gelijkstroomkabel is wereldwijd nog niet gebouwd. • De geplande accu-opslag van één gigawattuur is de grootste in zee tot nu toe.	• Ontwerp vanaf het begin een digitale "doppelganger" van het eiland zodat bouw en later onderhoud kunnen worden gesimuleerd. • Neem twintig procent technisch reservebudget op en lever installaties in stappen op, zodat elk onderdeel afzonderlijk kan worden getest voordat het in bedrijf gaat.
Beschikbaarheid en KPIs	Het moment waarop het eiland elektriciteit kan doorgeven hangt af van de oplevering van de windparken. • Voor de grote accu-opslag bestaan nog geen normcijfers voor beschikbaarheid.	• Stem de opleveringsplanning van het eiland nauwkeurig af op de aanbestedingskalender van de windparken. • Integreer een online conditiebewaking voor de accu-opslag in het energiebeheersysteem van het eiland.
Aanvoer van grondstoffen of inputzekerheid	Het eiland is vooral afhankelijk van windenergie, maar voor de waterstofproductie is ook	• Neem in het watercontract een regeling op voor leveringsbeperking tijdens droogte. • Onderzoek hergebruik van gezuiverd afvalwater op het eiland.

	zoet water nodig. • In het gebied komen regelmatig periodes van waterschaarste voor.	
Afzet en markttoegang	Het eiland wil elektriciteit en waterstof in vier landen verkopen; daarvoor zijn certificaten voor herkomst en duurzaamheid nodig.	Ontwikkel tegelijk met het technisch ontwerp een certificeringsroutekaart voor zowel elektriciteit als waterstof. • Onderzoek prijsafspraken met vaste subsidies of contracten-voor-verschil om marktrisico te beperken.
Milieu en Maatschappij	Het eiland biedt kansen voor een bijna-nul uitstoot profiel, maar er is nog geen concreet plan.	Stel vanaf de ontwerpfase een meetbaar doel voor netto-nul uitstoot op en laat dit valideren door een onafhankelijke organisatie. • Zorg dat alle bouwmaterialen en processen in de berekening worden meegenomen.
Nutvoorzieningen, ruimtebeslag en logistiek	• Honderd hectare ruimte is nodig voor kabelverbindingen, waterstof-installaties en logistiek. • De verschillende functies concurreren om dezelfde grond en infrastructuur.	Maak een groeimodel met uitbreidbare stukken eiland zodat er altijd ruimte voor nieuwe installaties blijft. • Simuleer de haven-, helikopter- en weglogistiek om opstoppingen te voorkomen.
Gezondheid, veiligheid en milieu incidenten	Het eiland ligt ver uit de kust en vereist een permanent evacuatie- en reddingsplan. • Er is nog geen contract met een reddingshelikopter-dienst.	• Sluit een contract met een reddingsdienst voor zoek- en reddingsoperaties en voer voor ingebruikname een volledige evacuatieoefening uit. • Laat het helikopterdek certificeren door een onafhankelijke veiligheidsinspectie.
Financien investeringen en bedrijfskosten	Het totale investeringsbedrag voor het eiland ligt tussen acht en twaalf miljard euro. • De operationele kosten worden sterk bepaald door maritieme bereikbaarheid en onderhoud aan de hoog-spanningskabels.	Neem een dubbele reserve op: twintig procent voor technische risico's en tien procent voor markt- en prijsschommelingen. • Maak het financieringsmodel modulair, zodat geld in stappen kan worden toegezegd naarmate mijlpalen worden behaald.

Appendix E: PESTEL Trend Analysis

PESTE trend analysis

Political

1. **Increasing Role of Geopolitical Tensions in Energy Transport Routes**
   In the next 4-6y, geopolitical tensions will continue to impact energy transport routes, with midstream companies having to diversify transportation corridors and establish contingency plans for disruptions.
   Challenges:
   Political instability, conflicts, or sanctions could disrupt transportation routes, leading to increased costs and delays. Companies will need to monitor geopolitical developments closely.

2. **Increased Nationalization of Natural Resources**
   Countries, particularly in Latin America and the Middle East, are increasingly nationalizing their oil and gas resources to exert greater control over production and revenue.
   Challenges:
   Over the next 4-6y, more countries will restrict access to foreign companies, favouring domestic entities and national oil companies, making market entry difficult for international players.

3. **Expansion of Government Support for Domestic Energy Security**
   In the next 2-4y, government support for domestic exploration will continue to grow, offering companies more favorable policies, faster permitting, and access to government-backed financing.
   Challenges:
   Balancing energy security with sustainability goals will be challenging, especially as countries aim to increase domestic production while adhering to international climate commitments.

4. **Political Pressure to Phase Out Fossil Fuels**
   Over the next 4-6y, refineries will face greater political pressure to pivot toward the production of biofuels and cleaner energy products, with stricter regulations on traditional fossil fuel refining.
   Challenges:
   Transitioning from fossil fuels to alternative energy products will be costly and complex, and refineries may face resistance from stakeholders who depend on fossil fuel revenues.

5. **Expansion of Government Support for Energy Infrastructure Resilience**
   In the next 2-4y, governments will provide more financial and political support for midstream companies to invest in resilient infrastructure, focusing on ensuring continuity of energy supply during crises.
   Challenges:
   Ensuring that midstream infrastructure is resilient to both physical and cyber threats requires significant investment and collaboration with government agencies. Non-compliance risks regulatory action.

Ecological

1. **Citizen-Led Renewable Energy Initiatives:**
   Over the next five years, citizen-led renewable energy initiatives are expected to expand due to continuing digital advancements and supportive EU policies promoting decentralized energy systems. The growing emphasis on energy security and sustainability will likely lead to increased public participation and investment in these initiatives.
   Challenges:
   As technology costs decrease and regulatory frameworks evolve to facilitate greater citizen involvement, these initiatives will play a pivotal role in achieving Europe's ambitious decarbonization targets. This evolution will further democratize energy production, empowering more communities to contribute directly to the sustainable energy landscape.

2. **Increased Political Pressure for Energy Decarbonization**
   Over the next 4-6y, midstream companies will need to make significant investments in renewable energy transportation and storage to meet political decarbonization targets.
   Challenges:
   Retrofitting existing infrastructure and building new facilities for renewable energy transportation is expensive and politically complex, requiring long-term government support and financing.

3. **Rise of Green Hydrogen Production**
   Over the next years, green hydrogen production in Europe is expected to scale significantly, enhancing energy security and supporting the decarbonization of multiple sectors. Technological advancements and cost reductions in electrolysis will improve the economic viability of green hydrogen, making it more accessible for industrial, municipal, and transportation applications.
   Challenges:
   Increased cross-border cooperation and the development of a robust hydrogen infrastructure, including pipelines and shipping routes, will facilitate a broader market integration, enabling efficient hydrogen distribution across the continent. This evolution will support a transition to cleaner industrial processes and mobility solutions, contributing to a more sustainable and resilient energy landscape in Europe.

4. **Increasing Water Scarcity**
   "As climate change progresses, Europe is poised to face escalating water scarcity, marked by more severe droughts and increasingly uneven water distribution. In response, technological advancements in water recycling and sustainable management practices are set to become more critical. European nations are anticipated to ramp up investments in innovative water-saving technologies and infrastructure, aiming to dynamically manage water demand and supply. Enhanced cooperation among EU countries will be crucial for effectively addressing cross-border water management challenges. This period is also expected to witness a significant shift towards integrating digital solutions for water management, promoting efficiency and resilience in water use across various sectors."
   Challenges:
   European policies, such as the Water Framework Directive and the Urban Wastewater Treatment Directive, strive to promote sustainable water use and improve drought resilience. However, the effectiveness of these policies is hampered by inconsistent

implementation across EU member states. This evolving water crisis demands a robust and integrated approach to water management, emphasizing the need for innovative strategies to ensure a reliable water supply for households, industries, and agricultural needs while maintaining environmental sustainability and adapting to changing climatic conditions.

Social

1. **Energy Poverty Alleviation:**
   As part of a broader push for climate neutrality, these measures will contribute to a more resilient and equitable energy system, ensuring that energy efficiency and sustainability are accessible to all, ultimately reducing the long-term incidence of energy poverty while promoting a healthier, more sustainable living environment across the continent.
   Challenges:
   Moving forward, Europe's strategy to combat energy poverty will increasingly leverage technological advancements and renewable energy integration. Focus will intensify on renovating older, inefficient buildings and expanding the use of smart energy solutions. Financial instruments and subsidies will likely become more targeted, supporting the poorest households directly.
2. **Public Push for Transparency in Energy Supply Chains**
   Over the next 2-4y, refineries and distributors will be expected to implement blockchain and other technologies to provide real-time data on the origins, carbon footprint, and processing of energy products.
   Challenges;
   Implementing supply chain transparency requires investment in digital infrastructure and poses cybersecurity risks. Ensuring accuracy and compliance with varying international standards is also challenging.
3. **Increasing Demand for Green Energy Transportation**
   In the next 6-8y, energy transport infrastructure will need to adapt to handle new forms of energy, such as hydrogen pipelines and biofuel storage, in response to public demand for sustainability.
   Challenges:
   Retrofitting existing infrastructure to transport greener energy forms will be costly and complex. Companies will need to invest heavily in new technologies while meeting safety and efficiency requirements.
4. **Growing Public Focus on Health and Safety in Energy Transportation**
   Over the next 4-6y, public pressure will push midstream companies to enhance safety measures, from more stringent safety inspections to deploying advanced monitoring technologies that ensure safer operations.
   Challenges
   Addressing public concerns while maintaining efficient operations will require significant investment in safety upgrades and new technologies, along with meeting more stringent regulatory requirements.

5. **Shift Toward Consumer-Centric Energy Solutions**
   In the next 4-6y, distributors will need to expand their infrastructure to cater to the rise in electric vehicles and home-based renewable energy solutions, integrating them with traditional energy systems.
   Challenges:
   Developing consumer-centric solutions requires substantial investment in new infrastructure, particularly in EV charging networks and smart grids, and will require partnerships with tech companies.
6. **Personalized Smart Services**
   Consumers will have more control over their utility management through apps that integrate usage data, pricing, and personalized recommendations. Privacy concerns will still shape the debate, but greater transparency and secure data management will be crucial for consumer trust. Ultimately, this will lead to more adaptive, responsive, and sustainable utility services across Europe.
   Challenges:
   As hyper-personalization deepens in essential utilities like energy, water, internet, and mobility, the trend will shift toward predictive and automated services. Utilities will harness AI and real-time data to anticipate user needs, adjusting energy consumption, water flow, or bandwidth automatically to optimize efficiency.

ˈechnological

1. **Advances in Carbon Capture and Utilization Technology**
   Over the next 4-6y, CCU technology will become more widely adopted in refineries, driven by stricter environmental regulations and government incentives, enabling more sustainable refinery operations.
   Challenges:
   High initial costs and technical complexity in implementing CCU systems in existing infrastructure will be a major hurdle for refineries, particularly in older facilities.
2. **Grid Modernization and Digitalization**
   Grid modernization and digitalization in Europe will continue to evolve, focusing on integrating more renewable energy sources and enhancing grid flexibility. The widespread adoption of digital twins, IoT, and smart meters will enable more efficient and reliable grid management. However, cybersecurity will remain a critical concern as the grid becomes more interconnected.
   Challenges:
   Regulatory frameworks and increased investments will drive the deployment of smart grids, fostering innovation and resilience. As digital tools and data infrastructure become more ubiquitous, Europe will progress toward a more sustainable and self-sufficient energy system, reducing its reliance on imported fossil fuels.
3. **Increasing Cyberattacks on Energy Infrastructure**
   The focus will likely shift towards integrating real-time threat detection systems and employing AI to enhance response strategies. Continuous investment in cybersecurity talent and technology will be pivotal in safeguarding utilities from cyberattacks, ensuring reliable service delivery to homes, businesses, and public sectors across Europe.
   Challenges:

As digital transformation deepens within Europe's energy sector, the sophistication of cyber threats will also evolve, posing complex challenges to grid stability, water supplies, and digital infrastructure management. Enhanced cybersecurity measures, cross-sector collaborations, and stringent EU regulations will shape proactive defences.

4. **Automation and AI-Driven Optimization in Distribution Networks**
   In the next 2-4y, AI-powered systems will be used to predict energy demand, optimize distribution routes, and enhance the precision of refinery output to match market needs more effectively.
   Challenges:
   The implementation of AI and automation requires significant investment in new technology and training. Integrating these systems with existing operations without causing disruptions will be a key challenge.
5. **Expansion of Hydrogen Transportation Infrastructure**
   Over the next 6-8y, investment in hydrogen-specific pipelines and storage solutions will expand significantly, with companies focusing on creating infrastructure that supports safe hydrogen transport.
   Challenges:
   Hydrogen is highly flammable and requires specialized materials for safe transportation. The cost of developing hydrogen infrastructure, combined with safety regulations, will be a major hurdle.

Economic

1. **Shift Toward Flexible Contracts in Energy Transportation**
   Flexible contract structures will become more prevalent in the next 2-4y, allowing companies to adjust rates and services based on market conditions and customer demand.
   Challenges:
   Shorter-term contracts can introduce financial volatility for midstream operators, as guaranteed revenue streams become less predictable. Balancing flexibility with stability will be crucial.

2. **Energy-As-A-Service (EaaS) Models**
   As EaaS continues to integrate with Europe's energy sectors, it will progressively influence the operational dynamics of utilities, municipalities, and diverse industries by offering tailored energy management solutions that enhance efficiency and sustainability. The convergence of EaaS with advanced digital technologies will facilitate smarter energy grids, foster the growth of decentralized energy systems, and enhance connectivity across utilities.
   Challenges:
   This shift will empower consumers and industries to actively participate in energy optimization, leading to more resilient energy systems and smarter cities. The broad adoption of EaaS is expected to catalyse innovations in energy storage and management, ultimately enhancing service delivery and customer engagement across various platforms. By aligning energy consumption with availability, particularly

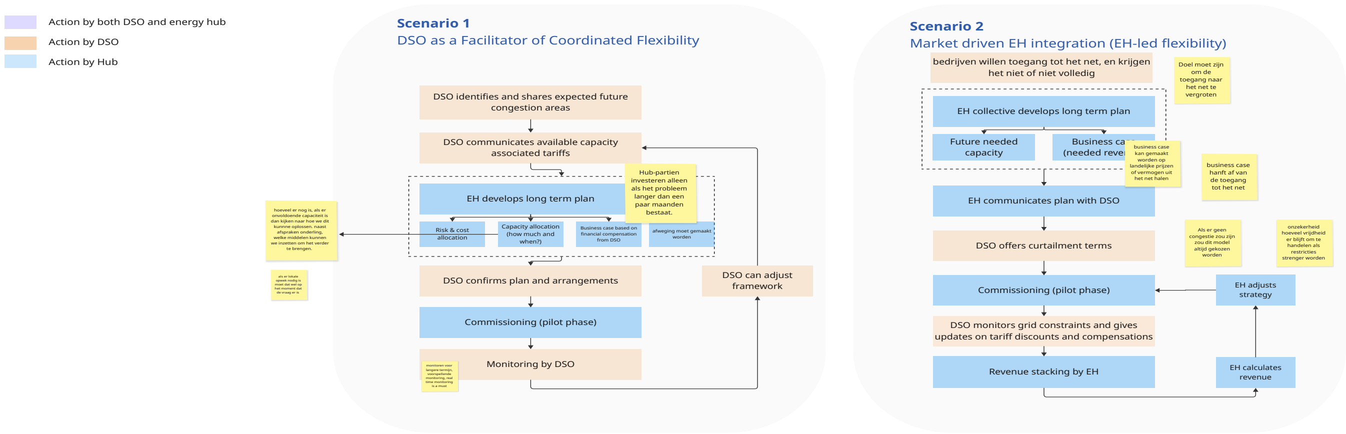
from renewable sources, EaaS supports a smoother transition to a low-carbon economy.

3. **Rising Investment in Green Energy Infrastructure**
   Over the next 4-6y, significant capital will be allocated toward building pipelines, storage tanks, and terminals for green energy, driven by government incentives and industry demand.
   Challenges:
   The transition to green energy infrastructure is expensive, and midstream companies will face challenges in securing financing while managing legacy fossil fuel investments.

4. **Rising Costs of Exploration in Remote Regions**
   Over the next 4-6y, exploration costs will continue to rise as companies push into remote and technically challenging areas, leading to more strategic partnerships to share costs.
   Challenges:
   High operational costs, technological risks, and fluctuating oil prices make this trend economically challenging. There is also a risk of stranded assets if global demand declines.

5. **Increasing Financial Pressure from Regulatory Compliance**
   Over the next 4-6y, financial pressure from regulatory compliance will continue to grow as companies invest more resources into meeting environmental standards.
   Challenges:
   Balancing the economic cost of regulatory compliance with profitability is a challenge. Companies that fail to comply with regulations risk fines, litigation, and reputational damage.

Appendix F: Workshop Miro Board



Task 1

Grab and rearrange the brackets, add requires actions and make arrow connections. please say aloud what you are doing and what you think.

Fill in

Fill in

Fill in

space for ideation

Task 2

Copy the post its, and fill in the table, in each row per scenario, what you think about the viability/ feasibility and desirability. Add notes with the yellow post its.

Fill in if you think the scenario is viable/ feasible/ desirable

Fill in if you think the scenario is not viable/ feasible/ desirable

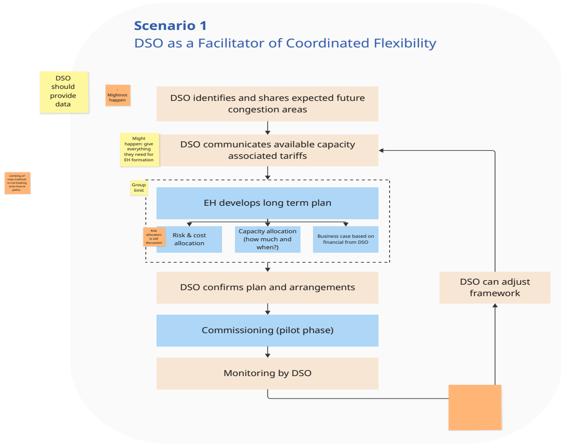
Notes

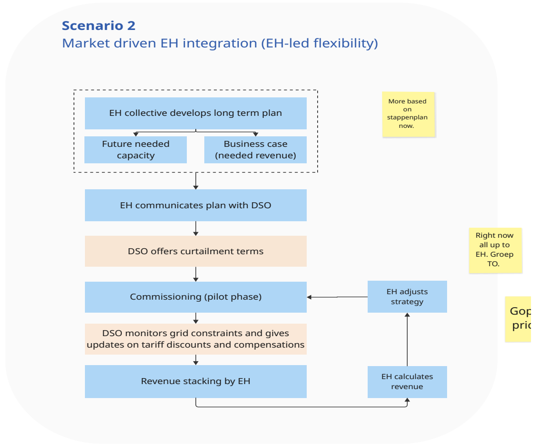
	Scenario 1 DSO as a Facilitator of Coordinated Flexibility	**Scenario 2** Market driven EH integration (EH-led flexibility)
Viability • Does this scenario offer a sustainable solution over the long term for all stakeholders?	investieringshorizon voor hub partijen is onduidelijk, als de congestie na een paar jaar wegvalt dan kan de business case insorten	risico op conflict tussen winst en netstabiliteit
Desirability • Would your organization benefit from this scenario? How? • Does this scenario align with broader energy transition goals?	Congestie vermijding en systeem efficienyie ondersteunt opwek van hernieuwbare energie	
Feasibility • Is it realistically possible to implement this scenario today? • Are the required technologies, capabilities and resources available to make this work?	Dso heeft rekencapaciteit nodig voor realtime sturing	investeringen vanuit hub hangen af van langere termijn contractzekerheid bedrijven kunnen de assets aanleggen maar alles eromheen nog niet

Action by both DSO and energy hub

Action by DSO

Action by Hub





Future will be combination of firm part and non firm, or flexible part (GOPACS)

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Task 1

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Fill in

space for ideation

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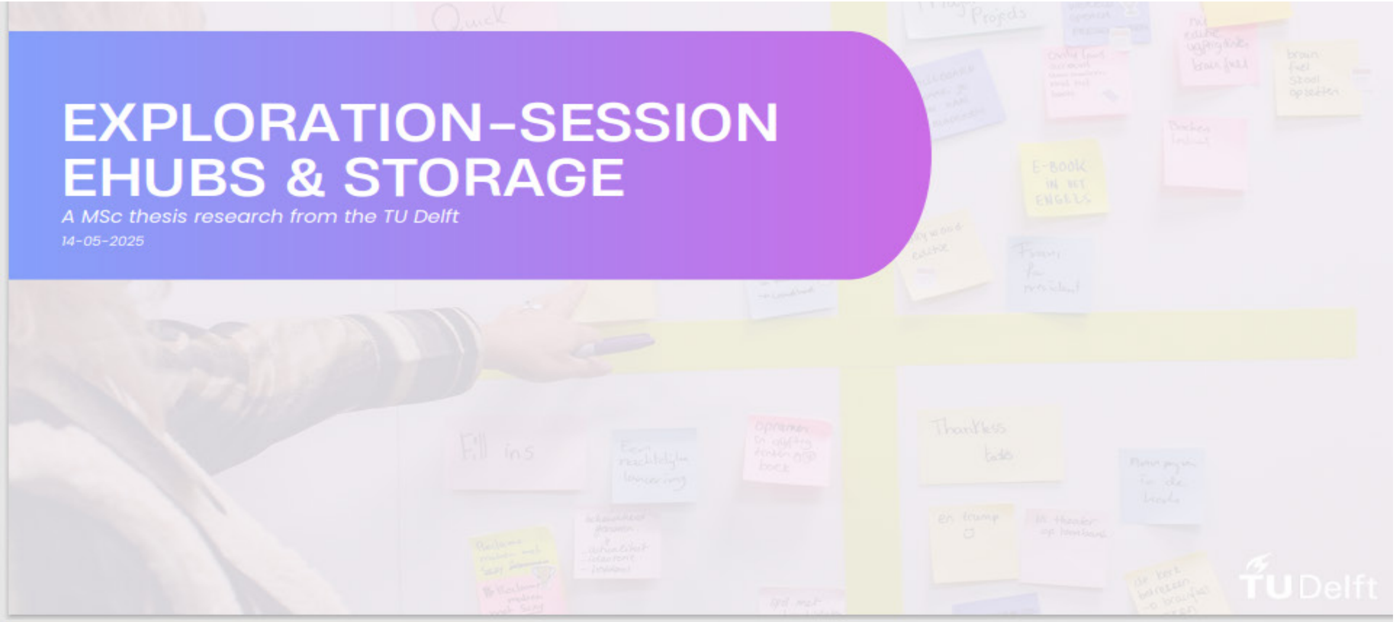
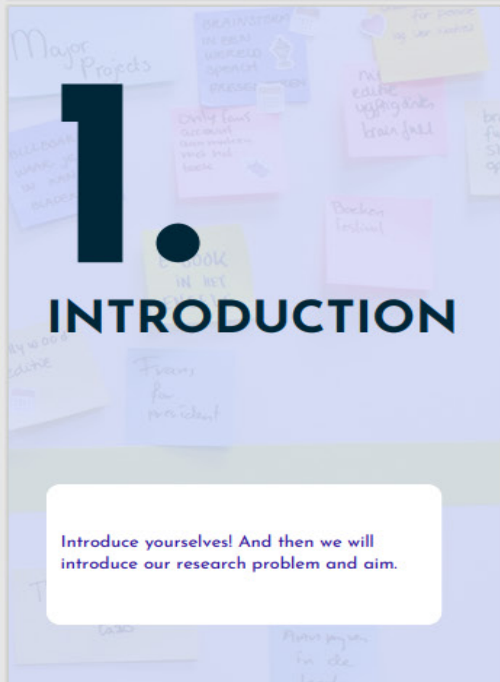
Fill in if you think the scenario is not viable/ feasible/ desirable

Notes

	Scenario 1 DSO as a Facilitator of Coordinated Flexibility	Scenario 2 Market driven EH integration (EH-led flexibility)
Viability • Does this scenario offer a sustainable solution over the long term for all stakeholders?		
Desirability • Would your organization benefit from this scenario? How? • Does this scenario align with broader energy transition goals?	EH: easy to understand, and know what they are getting DSO:	EH: lots of unclarity. Might have already DSO: with good appointmetts made it is desirable. Problem: lower capacity than expected. Capacity of network architect.
Feasibility • Is it realistically possible to implement this scenario today? • Are the required technologies, capabilities and resources available to make this work?	DSO as facilitator, DSO does not have products ready. We are not able to use data. DSO limits calculation methods	NO: contracts are not there yet - Data qualtiy - Data availability - contracts arent ready - Payment and procurement

Appendix G: Workshop Presentation





SITUATION

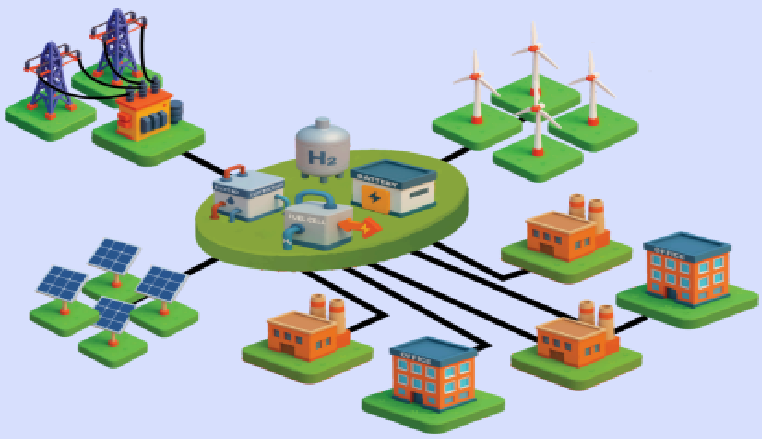
The electrification and growing share of decentralized renewable energy sources causes rising levels of congestion

Solving this problem by reinforcing the grid is too slow and too expensive

Congestion causes curtailment of renewable energy and limits industrial expansion.

SITUATION

Energy hub offers a solution by optimising local energy flow through smart management of local flexibility and storage technologies



COMPLICATION

In practice, the organization and coordination between involved parties appear to be the biggest obstacle to the realization of energy hubs with energy storage.

CONNECTION & CAPACITY

- Grid connection capacity allocation
- Grid connection strategies: uncertainty about securing timely and guaranteed connections.

ECONOMIC

- Profit models
- Cost sharing approaches: fair allocation of investment costs and financial risks.

OPERATIONAL

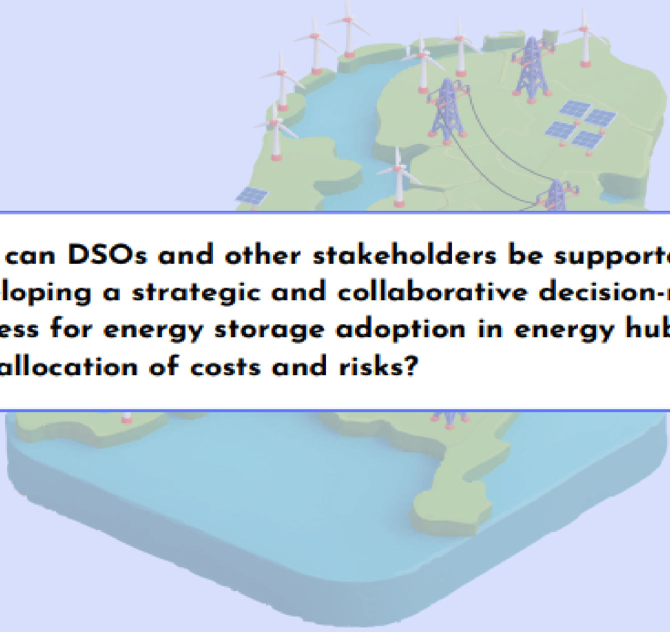
- Fair allocation of energy
- Operational timing: Battery storage also risks worsening congestion if not properly managed.

REGULATION & TARIFFS

- Grid operators aim to avoid investing in underused infrastructure, while energy hub developers need guaranteed access to secure funding.

A joint decision-making framework is needed that grid operators, and energy hub operators how energy storage can optimally contribute within energy hubs

QUESTION



How can DSOs and other stakeholders be supported in developing a strategic and collaborative decision-making process for energy storage adoption in energy hubs, including fair allocation of costs and risks?

2. NARRATIVE

Let us explain with the help of a narrative. We'd like to ask you reflective questions in between.

An example problem

At the edge of an industrial park, GreenForm Industries – a manufacturer focused on sustainable products – faces a critical bottleneck. Despite **plans to electrify** their production lines and **install solar panels**, the company is unable to secure a larger grid connection. With congestion on the local network, their growth and sustainability ambitions are stalled. GreenForm must find alternative solutions, as waiting for traditional grid reinforcement is no longer viable.

The problem

GreenForm collaborates with neighboring businesses to explore an energy hub (EH). While the DSO needs assurance that grid usage stays within limits, the businesses seek certainty over operational continuity and energy returns.

Uncertainty around who takes the lead, how costs and risks are shared, and what type of grid connection to pursue (firm or flexible) complicates progress.

An independent service provider models different EH configurations with shared battery storage for congestion management and local optimization, but questions remain about the business case's overall viability.

UNCLARTIY ON WHO LEADS THE EH INITIATIVE

AMBIGUITY ON COST AND RISK ALLOCATION

THE TYPE OF CONNECTION (FIRM VS FLEXIBLE) AND ITS EFFECT ON CURTAILMENT

Do you recognize this problem?
Are there any reflective remarks that you would like to add?

Finding the Solution

Clear agreements on grid usage, battery management, and revenue sharing are needed.

Future vision: GreenForm and the other participants manage their energy generation and consumption locally, and the shared battery also ensures flexibility services are available to the DSO. This arrangement enables GreenForm to continue expanding sustainably, while collectively contributing to easing local grid congestion.

LOCALLY MANAGING GENERATION AND CONSUMTION

FLEXIBILITY THROUGH THE SHARED BATTERY

CONTINUE EXPANDING WHILE DECREASING GRID CONGESTION

Do you agree with these benefits?
Are there any reflective remarks that you would like to add?

Three contract types:

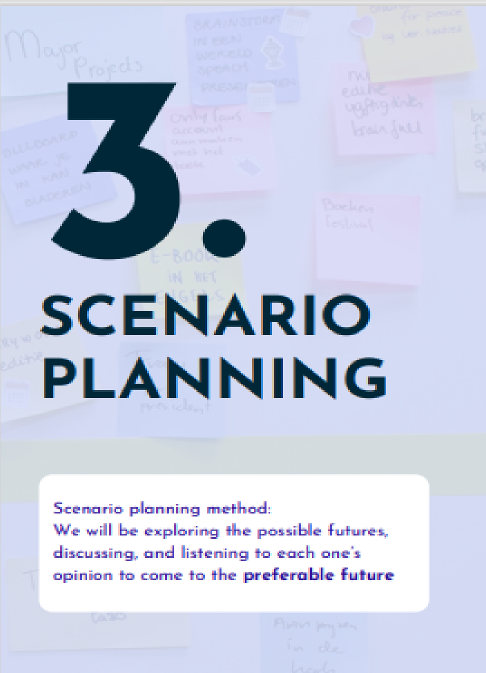
Contract type	Firm Group Transport Agreement	Collective Capacity Limiting Contract (C-CBC)	Non-firm Group Transport Agreement
Description	collective contract that replaces the individual transport agreement	collective contract that exists alongside the individual ATO.	This concerns a collective contract, without the right to transport, unless indicated
Grid access	Guaranteed access	Partial access (eg. 85% of the year)	No guaranteed access, only when there is enough space
Grid tariff	Full (standard) tariff	Standard tariff, but compensation for curtailed capacity	Great discount on tariffs (eg. 100% capacity charges Tennet)

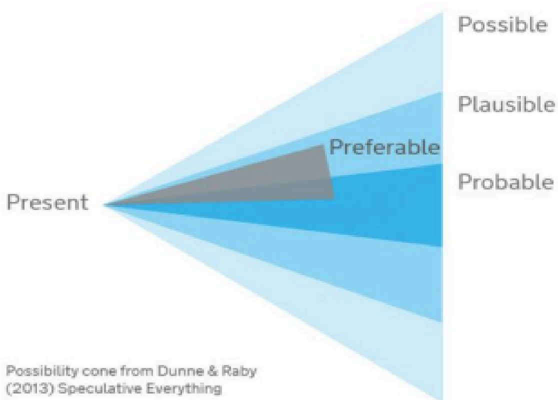
Three contract types:

Contract type	Utilisation fee only	Seasonal availability + utilization fee	Flat availability + utilization fee	Fixed annual fee
Payment model	Pay-per-MWh consumed during a constraint hour, based on the average avoided-curtailment rate.	Winter–summer availability fee (≈ 2x higher in winter) covering ≈ 70 % of fixed costs, plus a reduced utilisation fee. 10-year contract tendered 4 years ahead.	Same split as Option 2, but availability fee is uniform year-round.	Lump-sum payment for unconditional year-round availability; utilization fee optional or zero.
Producer	Bears the full volume risk; difficult to raise project finance without additional revenue streams.	Majority of fixed costs secured; bankable while retaining performance incentive.	Slight over-payment in summer and under-payment in winter; LCOH marginally higher than Option 2.	Maximum revenue certainty; easiest to finance.
Grid operator cost exposure	Pays only when congestion occurs; costs match real events but may spike unpredictably.	Pays a predictable seasonal retainer plus variable fees; cost profile aligned with congestion seasonality.	Simpler administration, but mis-prices seasonal risk; steady outlay regardless of actual congestion pattern.	High risk of over- or under-compensation if real congestion diverges from forecast; generally negotiated case-by-case.

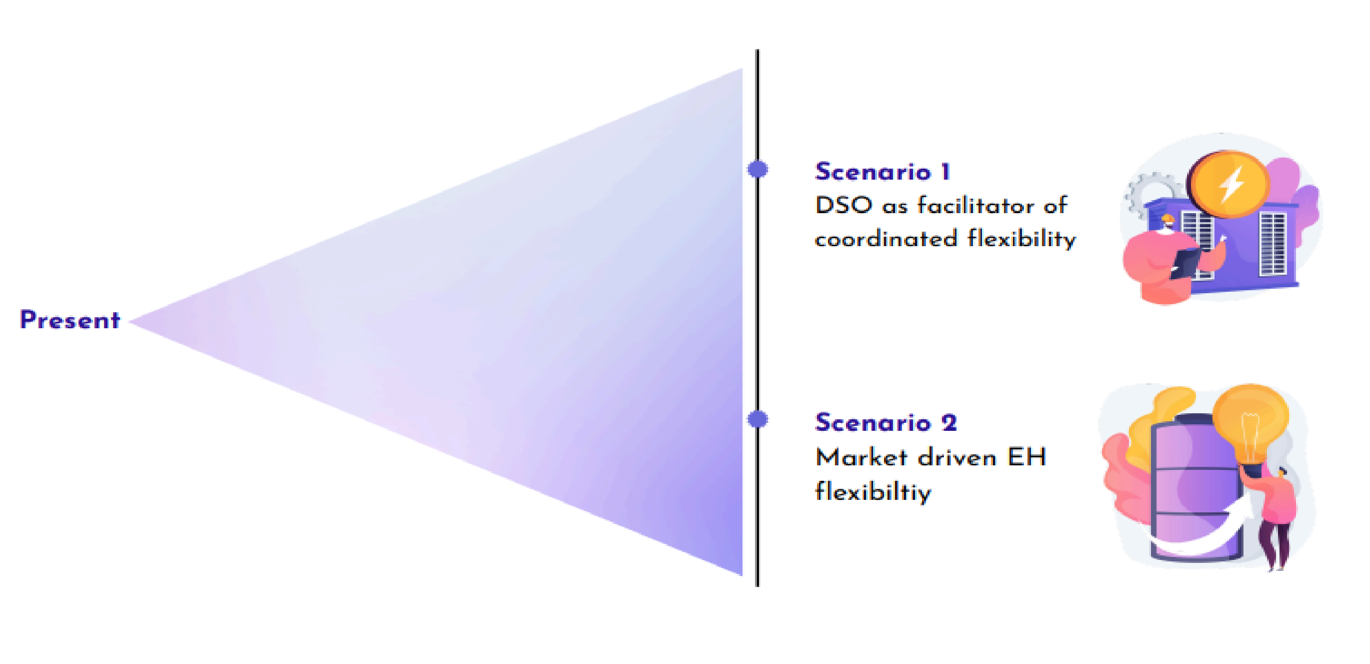
Do you have any remarks on this?

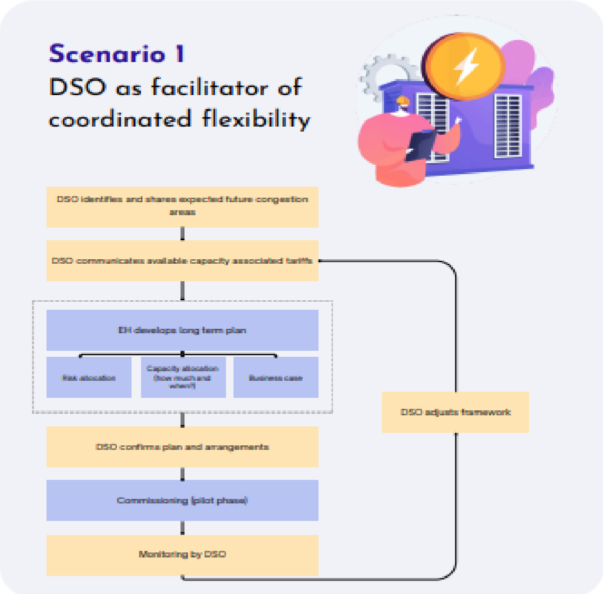
How to decide who has what role?
How to decide risk and capacity allocation?
What are the boundary conditions?

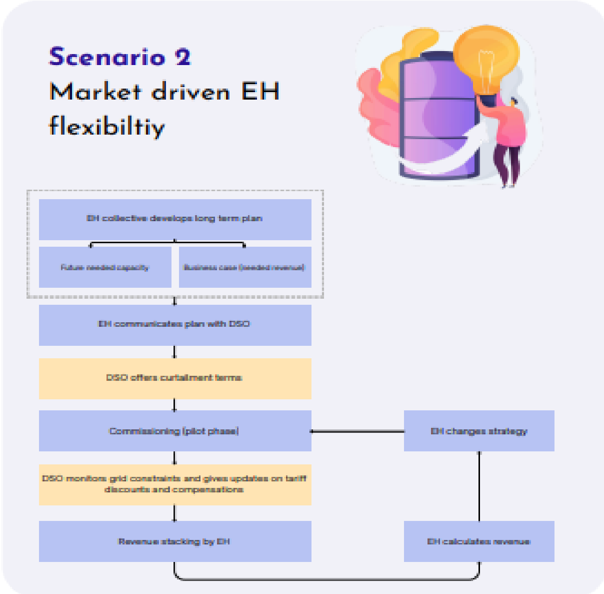




Possibility cone from Dunne & Raby (2013) Speculative Everything







We will move into break out rooms for discussions

Appendix G: Workshop hydrogen specific slides

An example problem

At the DeltaTech industrial park, a dozen manufacturers share a 12 MWh battery that shaves peaks and earns modest arbitrage income. The partners have bigger plans: adding induction furnaces, heat pumps and rooftop solar arrays to decarbonise their processes. But the regional DSO has just sounded the alarm. Its latest forecast shows that, within two years, the local 110 kV station will hit weekly congestion. The DSO warns it may freeze new connections and impose curtailment unless extra flexibility appears.

The problem

The hub's firms are willing to invest, yet every option seems to open a new set of questions. A larger battery looks simple, but the DSO doubts it will still be fast enough when solar output surges in five-minute bursts. Adding a PEM electrolyser could absorb those spikes and convert electricity into hydrogen—but who would own it, and would grid-service fees alone repay the stack? If the hydrogen must be sold, should the hub court mobility users, nearby boilers, or plan to reconvert it through a fuel cell? And if the DSO insists on a non-firm connection, who carries the revenue risk when production is curtailed?

Finding the Solution

To break the impasse, the park shifts focus to a single, integrative solution: installing a fast-ramping PEM electrolyser alongside the existing battery. By absorbing surplus renewable power within minutes and converting it into storable hydrogen, the unit would give the DSO the real-time flexibility it needs to avert congestion while unlocking a new energy carrier for DeltaTech's growth.

Success now depends on one shared framework. The partners must agree on technical sizing, risk allocation for stack life and safety upgrades, and a balanced tariff structure that rewards both grid relief and hydrogen valorisation. With these elements in place, the electrolyser becomes a common asset that lets the DSO keep the grid stable and allows DeltaTech's companies to expand their electrification plans without waiting for costly grid reinforcement.

Three contract types:

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