Feasibility studies for renewable energy projects

DANIDA Course: Physical & Financial Power Markets

Module T11

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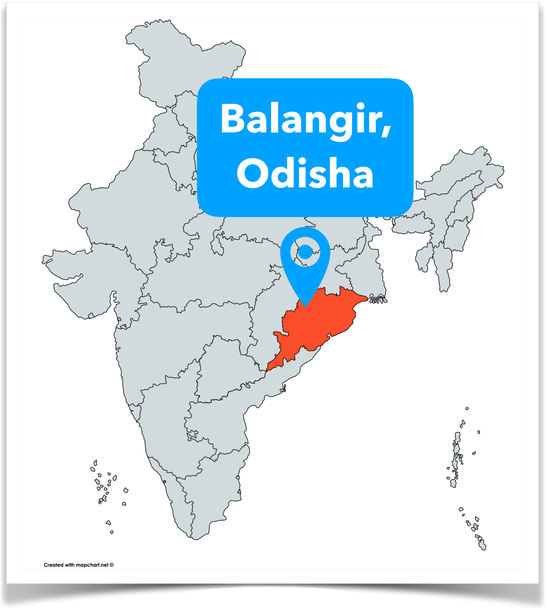
Plan

- Introductions
- Context
- Components of a feasibility study
- Project Greenopia: Case study
- Perspectives & reflections

Bio

- 2022 - now: Plant Optimization Specialist at Vestas Wind Systems
- 2019-2022: PhD in Electrical Engineering with focus on Energy Markets from DTU
- 2016-2018: Lead Analyst in General Electric, India
- 2013-2016: Co-founder & CTO, Shared Electric: Zurich based demand-response startup
- 2011-2013: M.Sc. in Energy Science & Technology from ETH Zurich



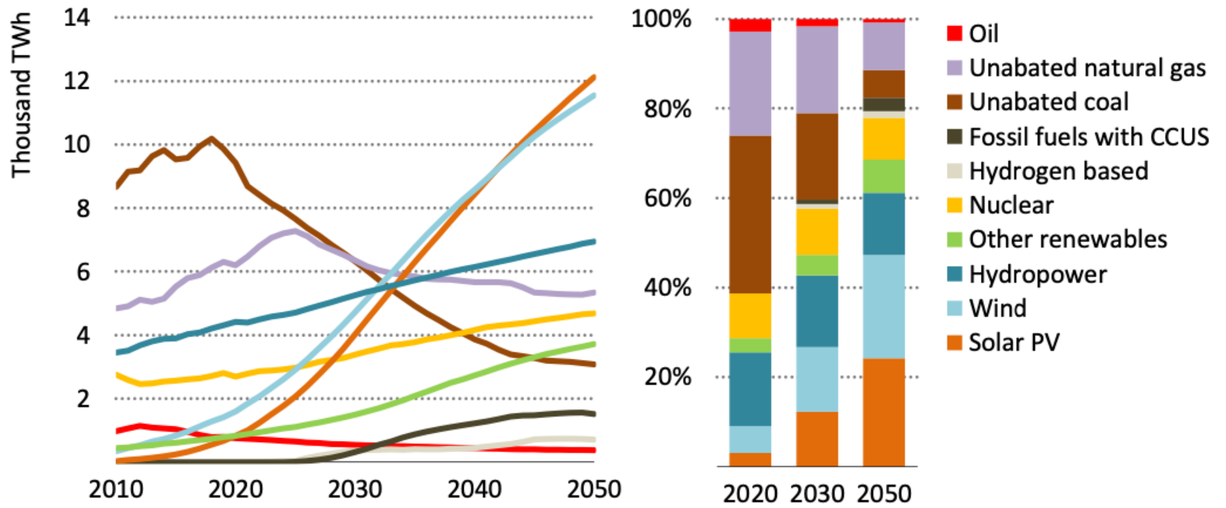
- Research interests:
  - Stochastic optimization, game theory, machine learning, data markets
  - Deeper decarbonisation via sector coupling, Power-to-X
  - Energy economics and policy

An existential challenge lies ahead…

Net zero emission goals hinge on **electrification** and **rapid renewables deployment**

- 2020s are a pivotal period for the energy world
- Electrification is a key pillar for net zero emissions
- Renewable energy projects must achieve **scale** and **speed**
- Needs **fast** and **reliable** project development

Global electricity generation by source, if all countries meet their pledges



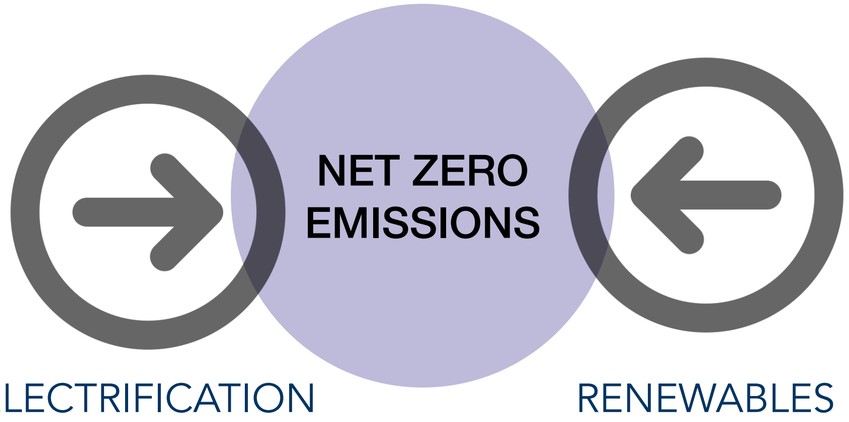


Figure Source: [R1]

Project maturity stages

OPPORTUNITY ASSESSMENT

- Is opportunity suitable?
- Which partners? What skills?

IDEA GENERATION

- Brainstorm possibilities
- Non-limiting, divergent

CONCEPT DEVELOPMENT

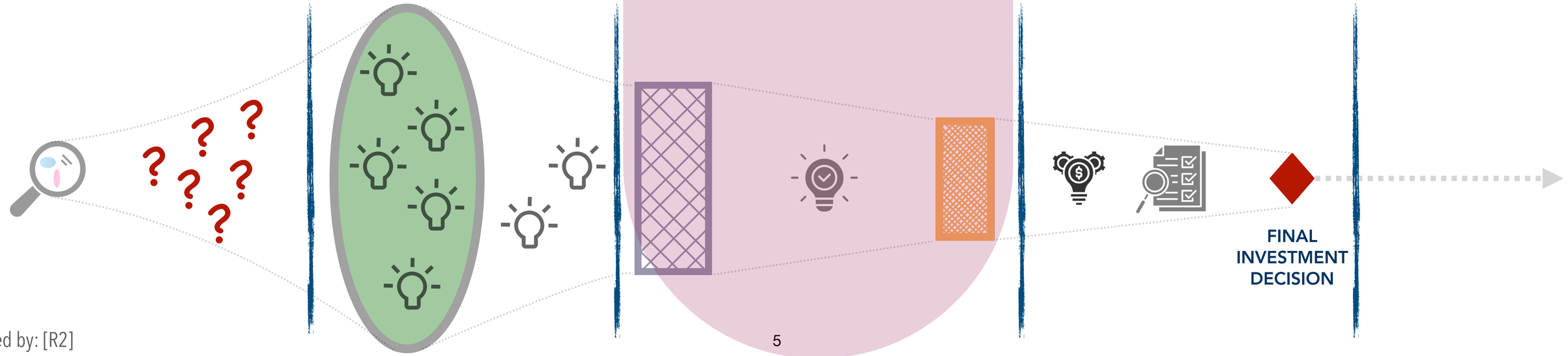
- Mature ideas to concepts
- Discard unattractive ideas

BUSINESS DEVELOPMENT

- Validate concepts
- Detailed design, sourcing of permits

PROJECT EXECUTION

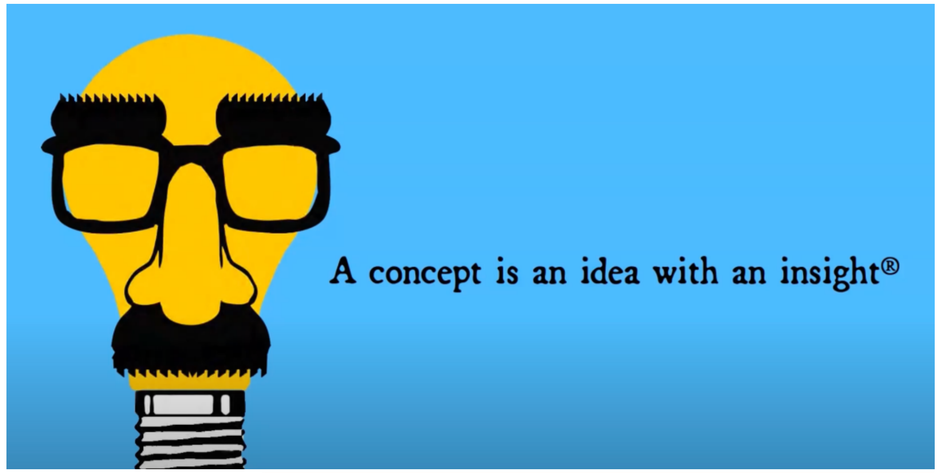
- Construction, civil works
- Installation, site tests

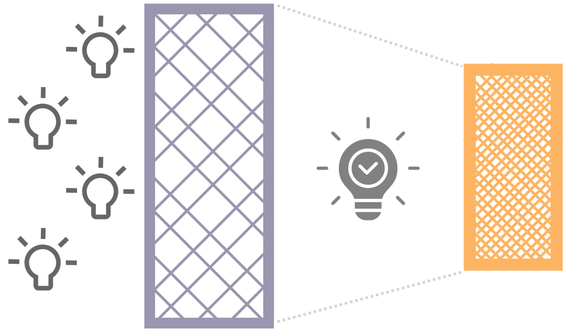


Inspired by: [R2]

Concept development

Mature **ideas** into technology **concepts**





IDEA

- General
- Open-ended
- Starting point

CONCEPT

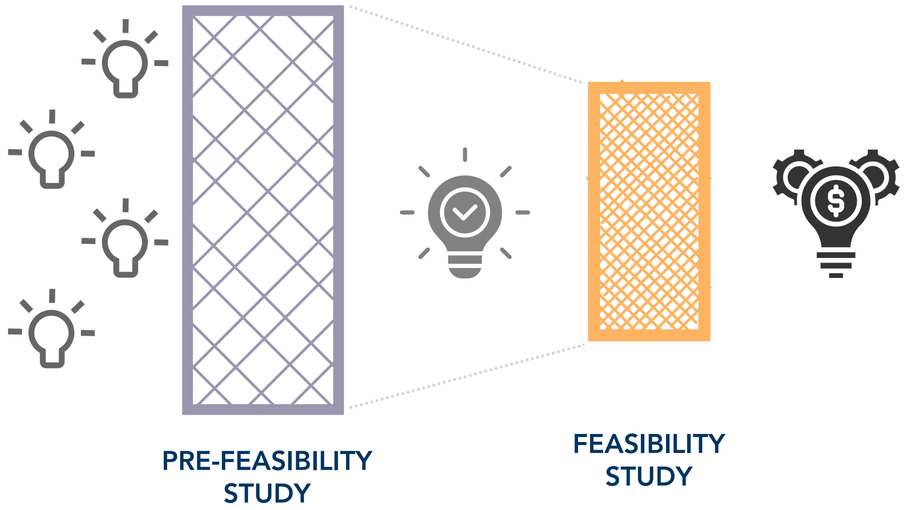
- Specific
- Well-defined
- Building block

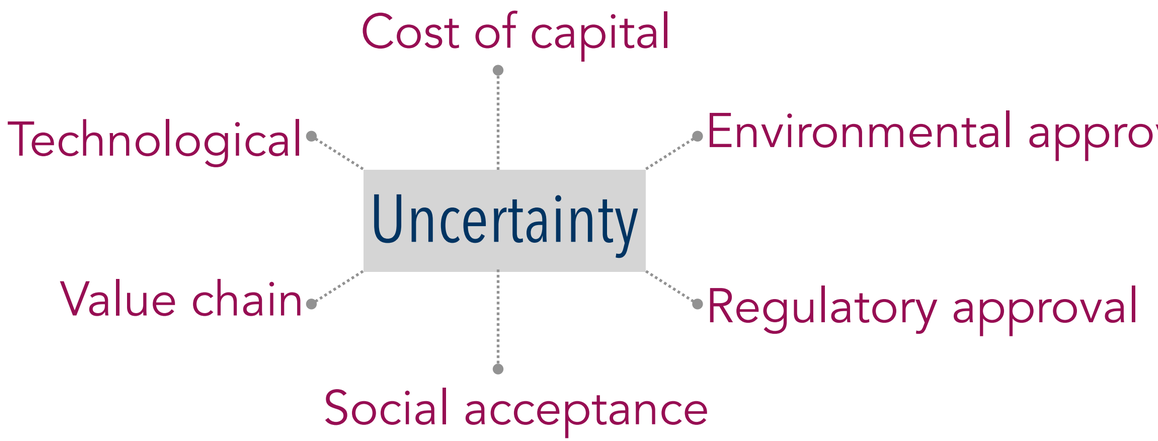
Source: https://www.printmag.com/design-culture/whats-the-difference-between-an-idea-and-a-concept/

Concept development

Mature ideas into technology concepts: Reduce **uncertainty** & lead to a **bankable** project

- **Pre-feasibility study (PFS)**: rough screening of ideas to mature a few concepts
- **Feasibility study (FS):** detailed screening of concepts to accept or reject them
- FS is just an in-depth PFS, with much closer analysis of uncertainty & bankability





Bankability or *perceived investibility:* The degree to which a project is able to secure financing from investors.

You would like to conduct a pre-feasibility study for a MW-scale renewable energy project.

What questions would you like that study to answer?
Who should you engage with during the study?

Discuss in your groups (5 minutes)

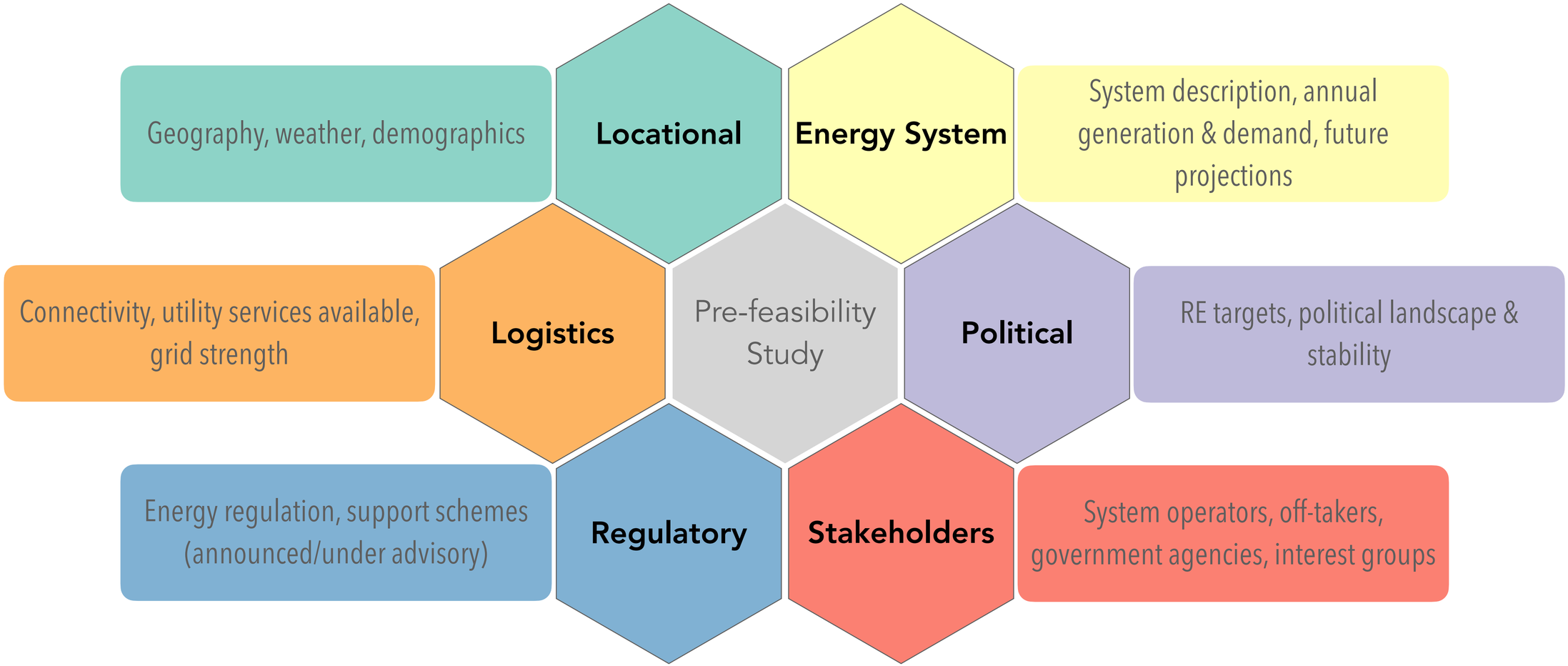
Pre-feasibility study: Questions

Preliminary systematic assessment of all critical elements of the project

- *Are there any regulatory aspects that could "**make or break**" this project?*
- *What about technologies - any **new entrants** in the market relevant for this project? Or any declining?*
- *Is the **expected revenue** enough to proceed with evaluating the project more?*
- *What about **profitability**?*
- *Does the prospective site pose any **environmental or social challenges**?*
- *What are the **identifiable risks** and uncertainties with this project?*

Pre-feasibility study: Contexts

Contexts define the background and scope for the project



Pre-feasibility Study: Components

1 RESOURCE ASSESSMENT

- Renewable resources
- Expected energy yield
- Other fuel sources

2 TECHNICAL ASSESSMENT

- Technical parameters
- Space requirements
- Grid perspectives

3 REVENUE STREAMS ASSESSMENT

- Revenue sources
- Support schemes or tariffs
- Regulatory barriers

4 FINANCIAL ANALYSIS

- CAPEX, OPEX estimation
- Economic feasibility: NPV
- Sensitivity analyses

5 ENVIRONMENTAL & SOCIAL ANALYSIS

- Environmental impacts
- Ecosystems disruption
- Social challenges

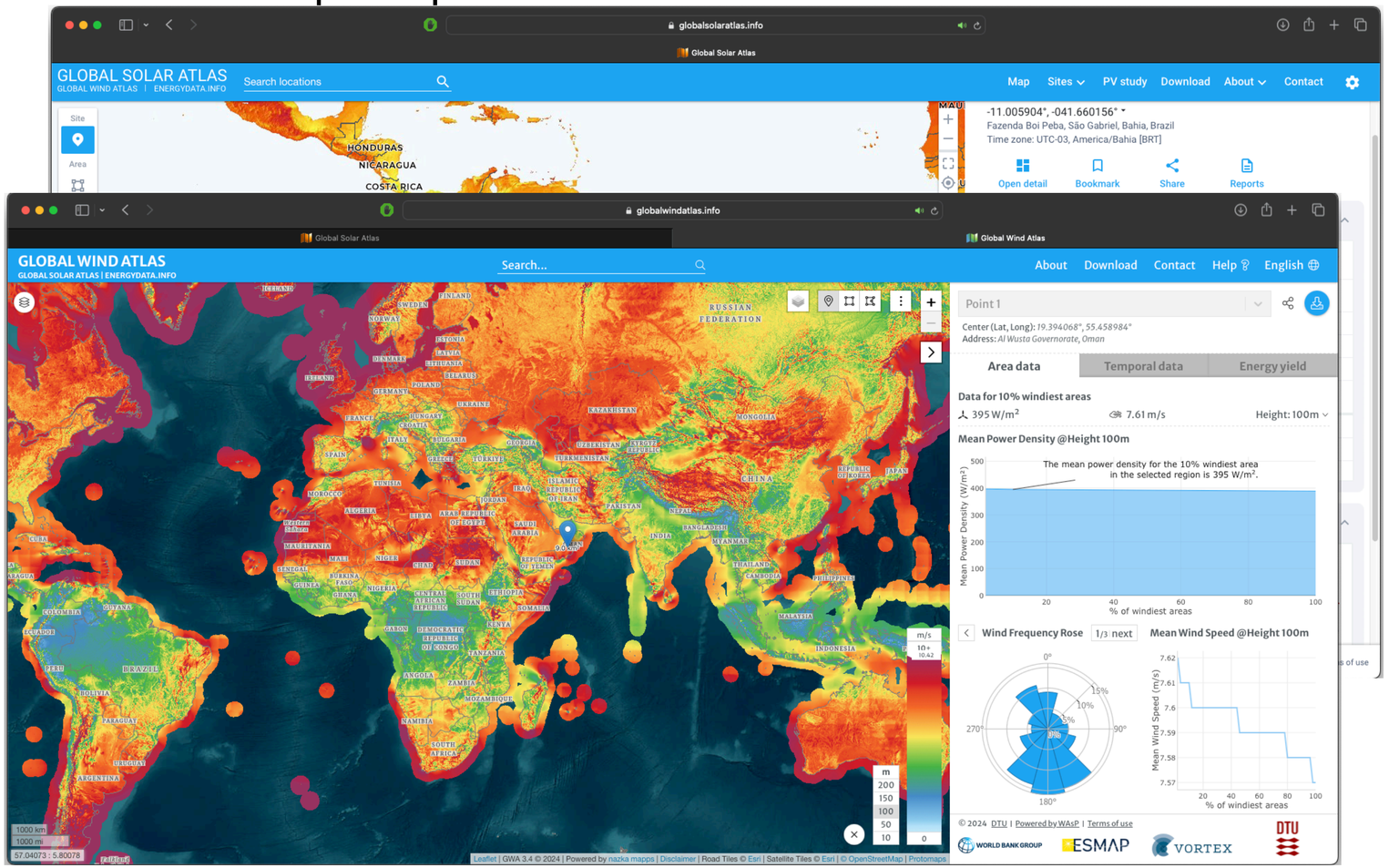
6 RISK ANALYSIS

- Risks evaluation: financial, political, regulatory, etc.
- Mitigation measures

What resources are available?

Mapping the **generation potential** for the prospective site

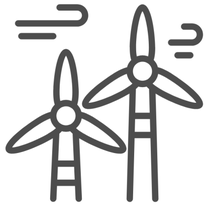
- Information sources:
  - GIS and open map tools
  - Data and reports from organisations, e.g., IRENA, NREL, IEA, Our World in Data, etc.
  - Country-specific energy databases
- **Solar:** Global Solar Atlas, PVsim, PVgis
- **Wind:** Global Wind Atlas, WindPro, WaSP

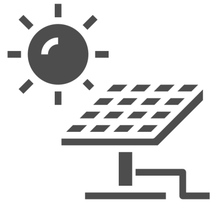


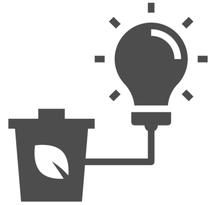
Sources: 1. Global Solar Atlas: https://globalsolaratlas.info, 2. Global Wind Atlas: https://globalwindatlas.info, 3. Visualising Energy: https://visualizingenergy.org/what-countries-have-the-greatest-bioenergy-power-capacity/, 4. Global Energy Monitor: https://globalenergymonitor.org/projects/global-hydropower-tracker/tracker-map/

Which renewable technologies are suitable?

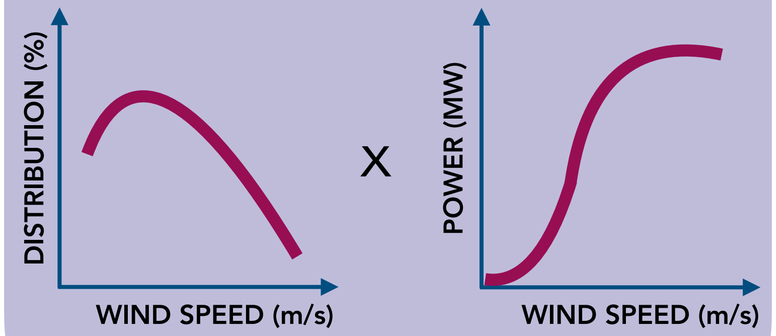
Evaluating the various **renewable energy options** w.r.t. the **resources available**







Annual Energy Production (AEP) in MWh

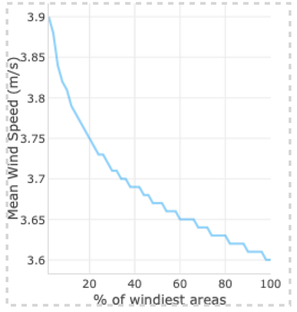


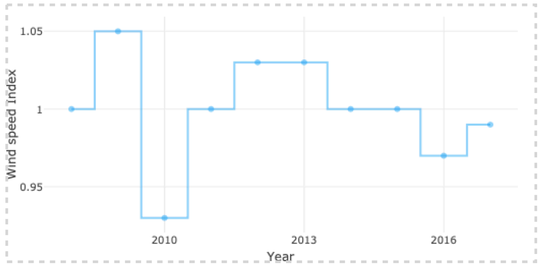
Annual Energy Production (AEP) in MWh

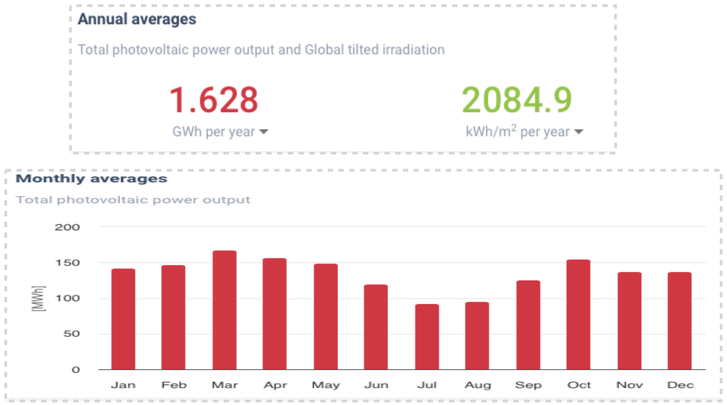
- Global Horizontal Irradiance (GHI)
- System characteristics: panel properties, tracking system, etc.

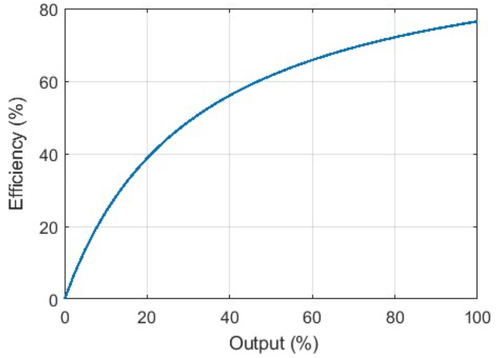
Annual Energy Production (AEP) in MWh

- Biomass feedstock (fuel) availability and quality
- Plant efficiency could depend on loading level
- Shutdown and startup periods









Which technologies to choose and what sizes?

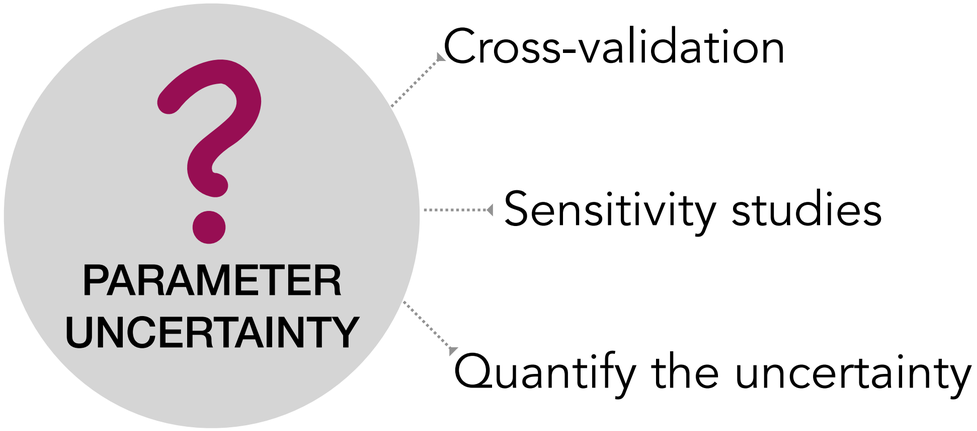
How to **dimension** the project, given the **resource availability** and **technical constraints**?

Site-specific Technical parameters

- INSTALLED CAPACITY (MW)
- ESTIMATED CAPACITY FACTOR (%)
- TECHNICAL LIFETIME (years)
- FOOTPRINT (sq.m./ MW)
- EXP. CURTAILMENT COSTS ($)
- EXP. LOST PRODUCTION (% hours)
- CAPACITY DEGRADATION (%/year)
- EFFICIENCY, POWER CURVE, etc.
- MUST-RUN HOURS, STARTUP/SHUTDOWN COST

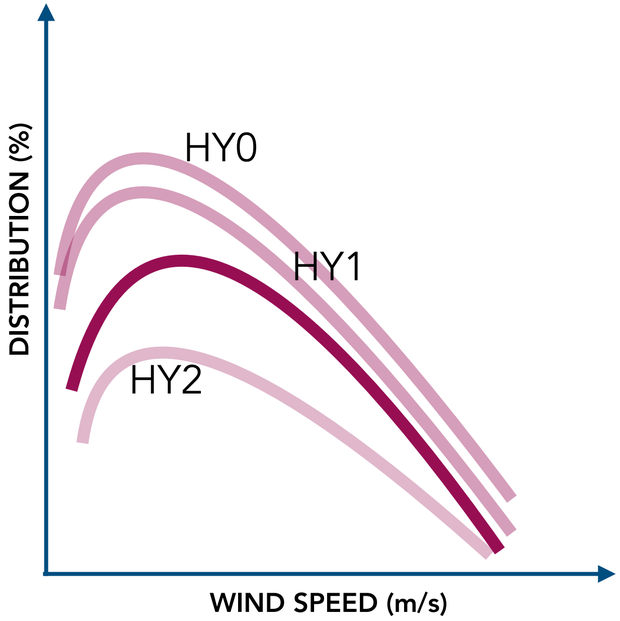
- Sources:
  - Scientific and practitioners' literature
  - Catalogues published by and interviews with manufacturers
  - Publications from professional organisations

A number of parameters may need to be estimated!



AEP uncertainty can bring in great risk

Data from **historical years (HY)** can help **quantify AEP uncertainty**



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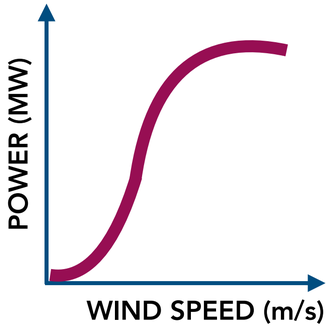

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$$[\underline{AEP}, \overline{AEP}]$$

or

$$\{AEP_{p10}, AEP_{p20}, AEP_{p50}, AEP_{p90}\}$$

Do you agree? Why? Why not?

Is there something you could at the pre-feasibility study stage to account for it?

Uncertainty for AEP from solar PV can be quantified similarly to reduce risk.

Pre-feasibility Study: Components

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4 FINANCIAL ANALYSIS

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- Sensitivity analyses

How will the project make money?

Revenue streams must be considered in light of the **inherent risks & uncertainty**

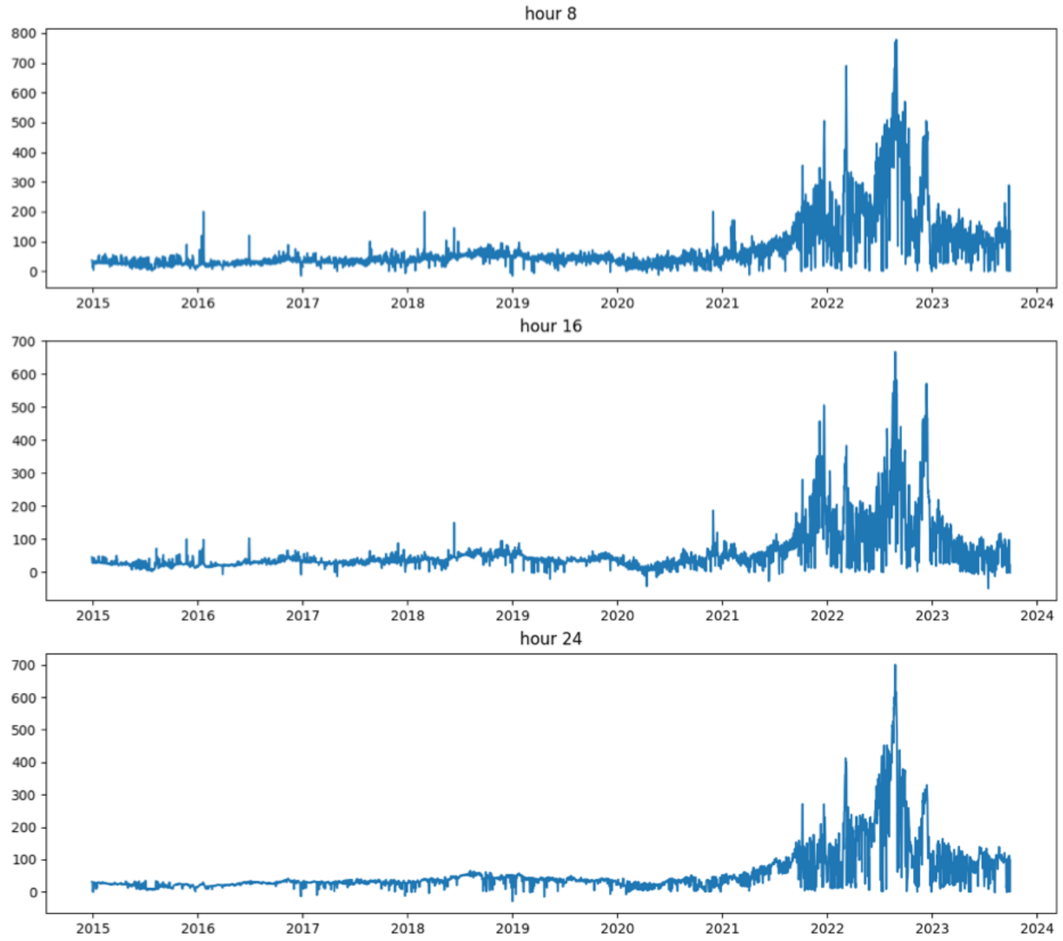
FINANCIAL SUPPORT + POWER PURCHASE AGREEMENT + MERCHANT MARKET

Bankability
- Revenue stacking
- Additional streams

Analyse available renewable support mechanisms: type, duration, conditions, obligations, tax implications, etc.	Policy Risk	Project developed under different assumptions regarding support
Analyse average system generation cost and procurement regulation, identify & screen potential PPA off-takers	Contract risk	Annual energy production estimated incorrectly and PPA clauses can trigger penalties
Analyse historical and projected power prices, demand growth & risk of oversupply, identify off-takers with market price risk appetite	Market Risk	Unexpected oversupply in the market leads to depressed merchant market prices

Notice anything interesting in this graph?

Merchant risk: Higher than anticipated **price volatility** can make **cost of capital high**!



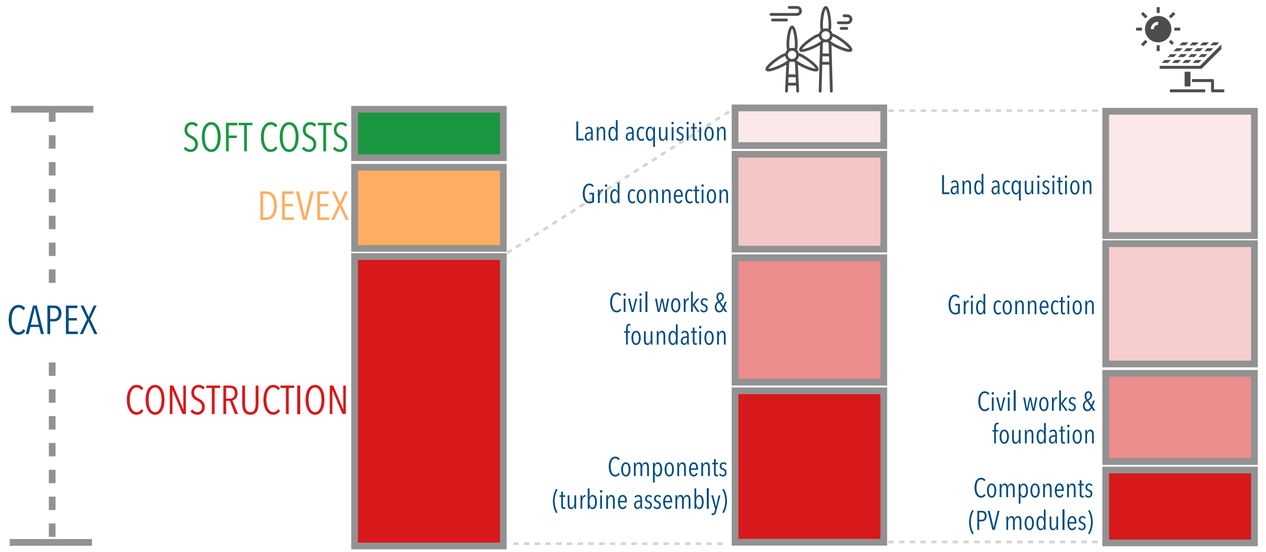
Day-ahead prices in DK2 zone in hours 8, 16 and 24 from 2015 to Sep 2023

Figure source: Anders Linnemann Nielsen *(2023), Analysis of day-ahead prices and influencing factors in the Nordic power market, M.Sc. Thesis, Aalborg University.*

What will the project cost during its lifetime?

Estimating and understanding the **cost structure** of the project

- Project lifetime cost = CAPEX + OPEX
- Wind & Solar Capital Expenses (CAPEX): occur even before the first kW is produced!
- Development Expenses (DEVEX): occur even before FID is made!
- Soft costs: financing, overhead costs, decommissioning
- Consider cost changes due to project lead-time!
- Grid connection costs: Shallow vs deep?



What % of project lifetime costs is CAPEX for solar & wind projects?

What about fossil-fuel based power plants?

How to evaluate if the project will make money?

Discounted Cash Flow (DCF) method is a standard approach

Discounting

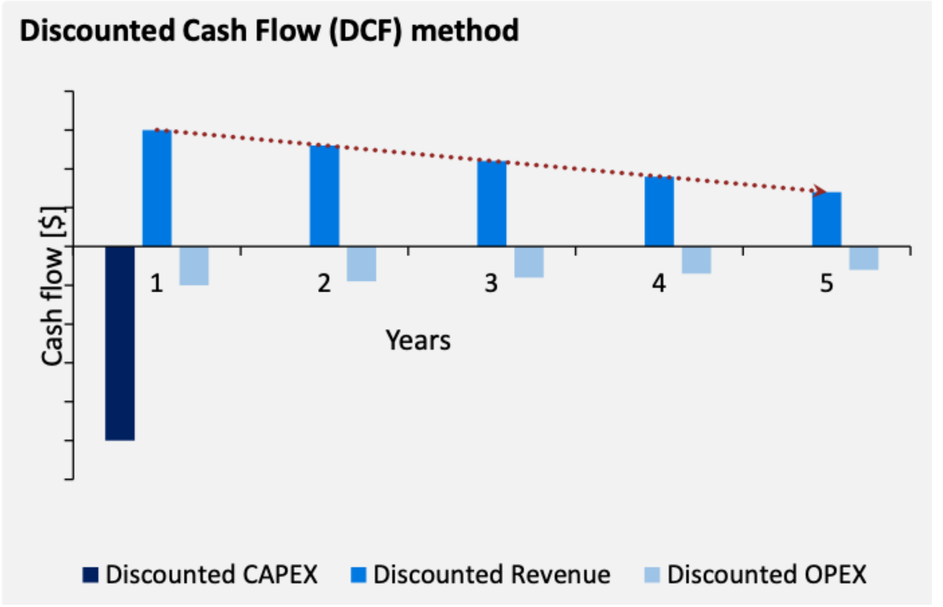
- Cash flows in later years are **discounted** using a discount rate *r* %
- Discount rate aka **Cost of Capital** *r* is crucial

Weighted Cost of Capital (WACC) { Rate at which a company is expected to pay on average to investors to attract project financing

EQUITY FINANCING

vs

DEBT FINANCING



Source: [R2]

Is the project bankable?

Net Present Value (NPV) > 0 is a requirement for financial feasibility.

Net Present Value (NPV)

What is the project worth to us today based on the discounted cash flows (CFs).
Good for comparing various projects, irrespective of how investments & cashflows are structured.

$$NPV = -CF_0 + \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t}$$, where T = Project lifetime (years), r = discount rate (%)

Internal Rate or Return (IRR)

Shows the annual return a project is expected to yield.
It is essentially the discount rate that leads to an NPV of 0 at the end of project lifetime.

$$0 = -CF_0 + \sum_{t=1}^{T} \frac{CF_t}{(1+IRR)^t}$$

Levelized Cost of Energy (LCOE)

Shows the average cost of a project over its lifetime, including the cost of capital.
Used to compare technologies and tracking their maturity over the years.***

$$LCOE\ (\$/MWh) = \frac{\sum_{t=1}^{T} \frac{CAPEX_t + OPEX_t}{(1+r)^t}}{\sum_{t=1}^{T} \frac{AEP_t}{(1+r)^t}}$$, where $CAPEX_t$, $OPEX_t$ are in $ and AEP_t is in MWh

Project Greenopia: A Case Study

Refer to the document in Canvas

Discuss and work in your groups (25 minutes)

Pre-feasibility Study: Components

1 RESOURCE ASSESSMENT

- Renewable resources
- Expected energy yield
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- Space requirements
- Grid perspectives

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- Environmental impacts
- Ecosystems disruption
- Social challenges

6 RISK ANALYSIS

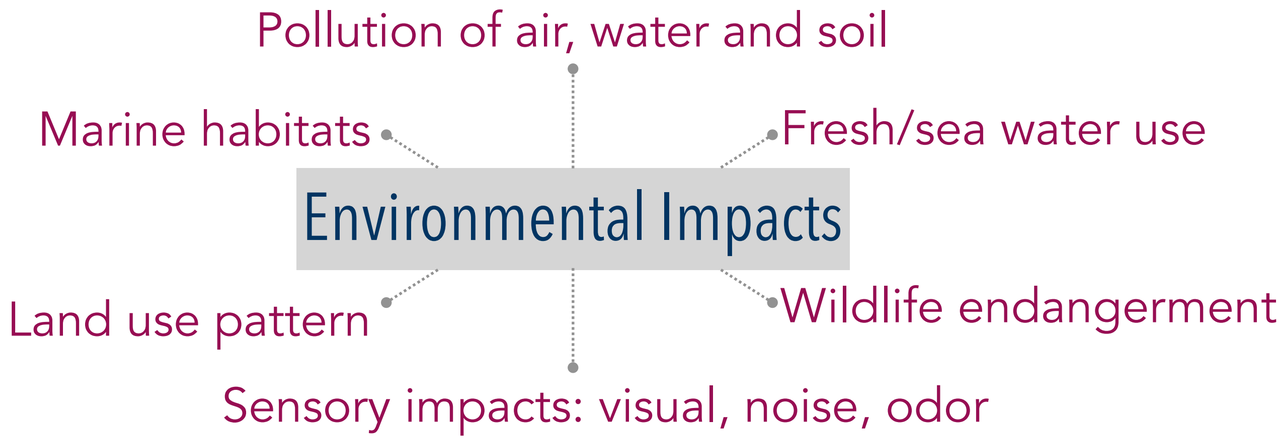
- Risks evaluation: financial, political, regulatory, etc.
- Mitigation measures

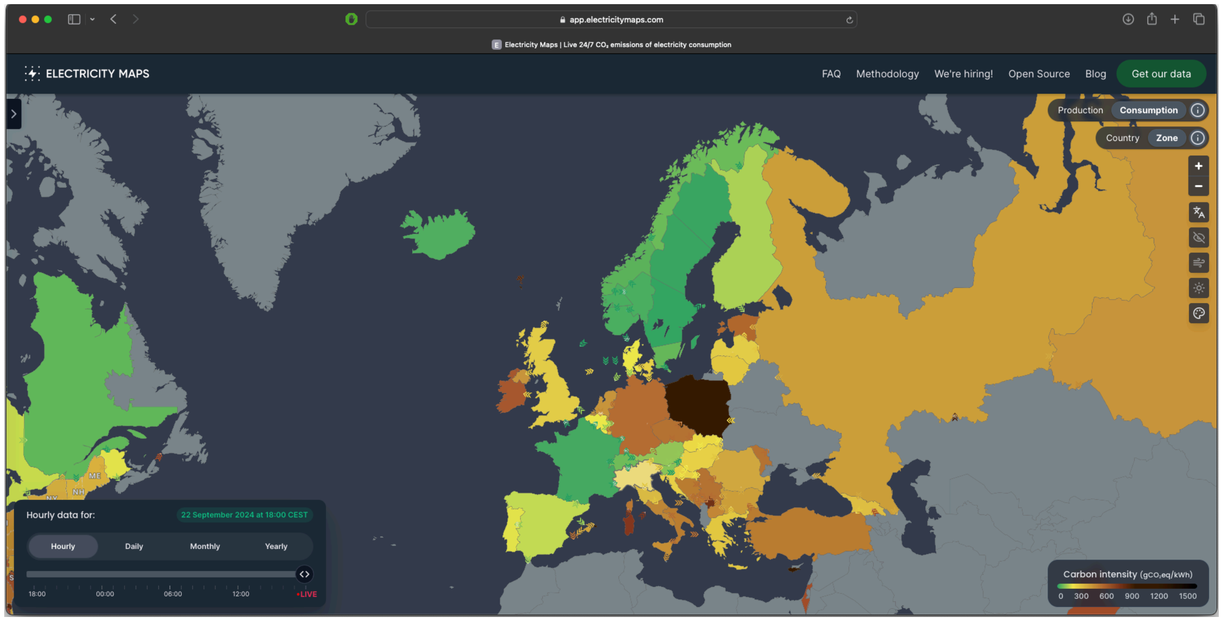
Will the project cause environmental and social issues?

One of **riskiest components to ignore**

- Can truly "make or break" a project if identified too late!
- Identify and map the concerns, initiate stakeholder engagement to address them

Don't forget to highlight the positive climate impact, i.e., emissions avoided.

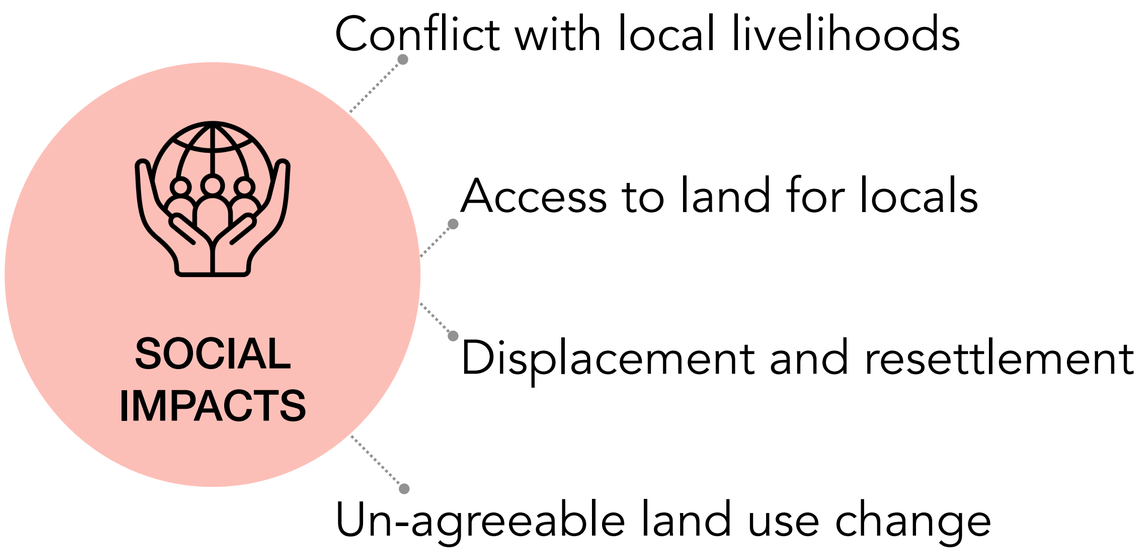




Source: Electricity Maps: https://app.electricitymaps.com

Do not ignore identifying local community impact

Sustainability is multi-dimensional



Norway ends dispute with reindeer herders over wind farm

By **Reuters**

March 6, 2024 3:30 PM GMT+1 · Updated 6 months ago

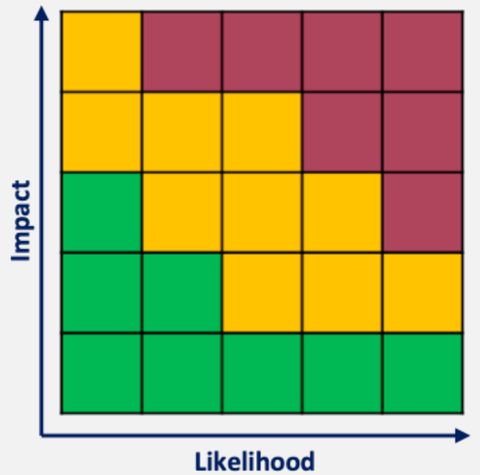
How sensitive is the project to context changes?

Risks should be **identified, screened and tagged** with mitigation measures

- Four broad categories:
  - Political risks
  - Economic risks
  - Technical risks
  - Social risks

Risk Matrix

- Plots **Likelihood vs Impact** for the identified risks
- Likelihood is estimated as a level of **probability**
- Impact is normally estimated in terms of **potential capital loss**



Source: [R2]

Policy Risk	Project developed under different assumptions regarding support
Contract risk	Annual energy production estimated incorrectly and PPA clauses can trigger penalties
Market Risk	Unexpected oversupply in the market leads to depressed merchant market prices

Project Greenopia: Risk Analysis

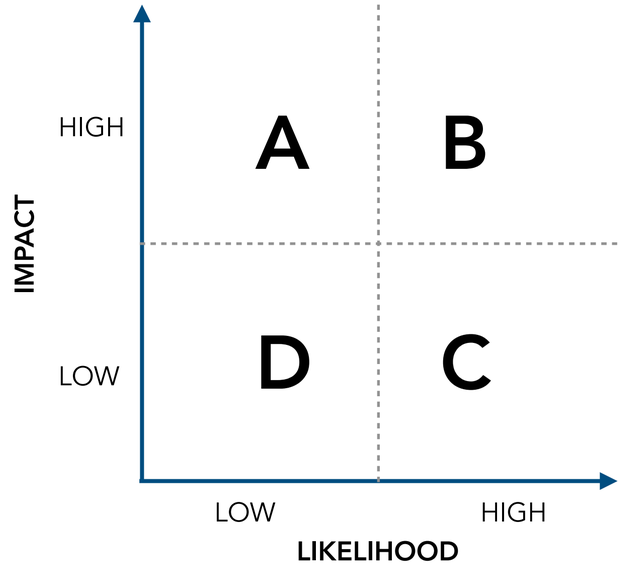
We already discussed a few risks (above) during the lecture.

Discuss in your group:

1. Which broad category do they belong to? What would you do to mitigate the above risks? Do they exist for Project Greenopia?

2. What other risks can you think of for Project Greenopia? Think of at least two more and suggest ways to mitigate them?

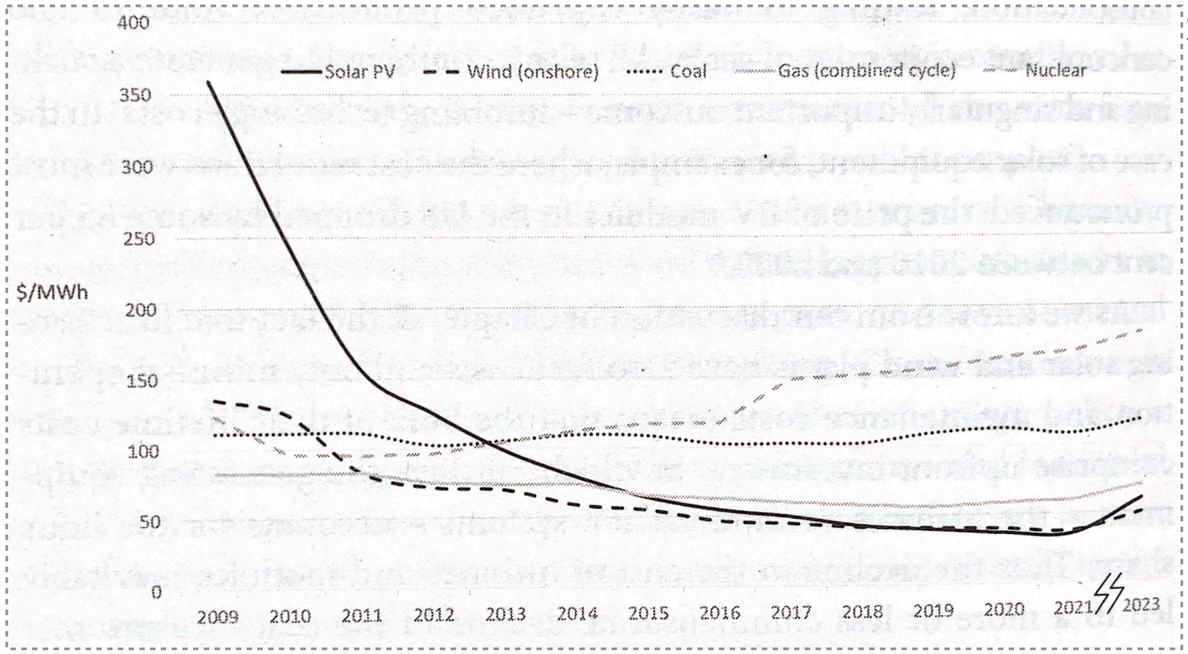
3. Roughly and intuitively, which region (A, B,C, or D) of a Risk Matrix would you put these risks in?



(10 minutes)

The “incomplete” story of LCOE

Wind onshore & solar are **much cheaper** than fossil fuels since 2015



Source: [R5]

Levelized cost of electricity (LCOE) by source of generation, 2009 - 2023 (utility-scale, unsubsidised, mean value)

Why are projects not accelerating?

Profitability and **not low LCOE** rules - *Investors don’t really care for climate change!*

Higher profitability at lower risk → Investment

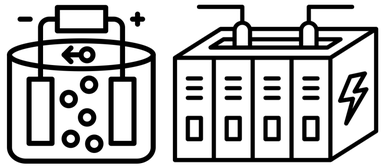
Feasibility studies should focus on **de-risking revenue streams**

Grid Services

Examples: Round-the-clock tenders (India), ancillary services (Nordics), grid services-based connectivity priority (Spain)

Pros: Improve bankability, reduce uncertainty & variability in grid, faster permitting process

Cons: Potentially higher market risk, complex tender criteria, improved grid integration testing



Behind-the-meter Assets

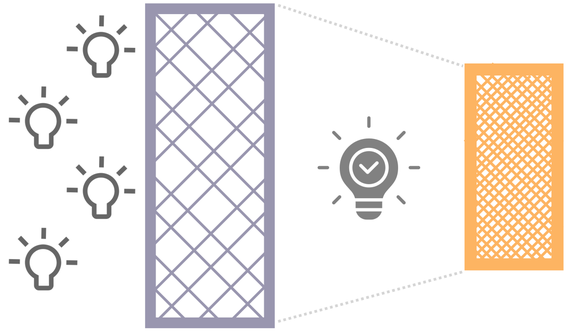
Examples: Power-to-X, energy storage

Pros: Improve bankability, reduce curtailment, longer-term storage of electricity

Cons: Complex physics of assets, multiple new sectors coupled, new supply chains

Perspectives

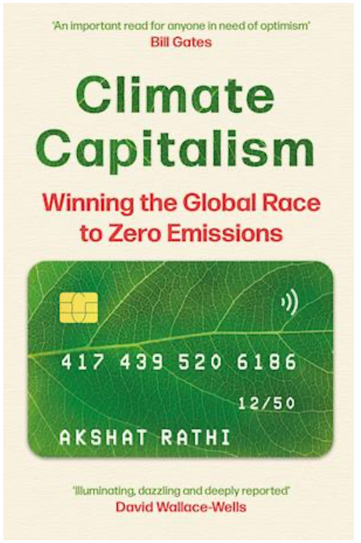
From pre-feasibility study to **feasibility** and **bankability**



- Focus on uncertainty reduction and validate the business case
- Break down project into phases as a de-risking measure
- Make your feasibility studies rigorous
- Identify, map, and mitigate all risks as best as you can
- Multi-disciplinary nature - engage stakeholders early
- Validate all your assumptions
- Leave no revenue stone unturned

How would you extend your pre-feasibility study outcome to a feasibility study?

Two books, Two Outlooks



Reflections & Questions?

Further reading

- **[R1]** International Energy Agency (2021). *Net Zero by 2050: A roadmap for the global energy sector.* IEA, Paris iea.li/nzeroadmap
- **[R2]** Danish Energy Agency, Viegand Maagøe, EA Energy Analyses. *Pre-feasibility studies guidelines.* https://ens.dk/sites/ens.dk/files/Globalcooperation/prefeasibility_study_guidelines_final.pdf
- **[R3]** International Energy Agency (2022). *World Energy Outlook 2022*. IEA, Paris. https://www.iea.org/reports/world-energy-outlook-2022
- **[R4]** Institute for Energy Economics and Financial Analysis (2021). *Understanding round-the-clock tenders in India* https://ieefa.org/wp-content/uploads/2021/11/Understanding-Round-the-Clock-Tenders-in-India_November-2021.pdf
- **[R5]** Brett Christophers (2024). *The Price is Wrong: Why capitalism won't save the planet.* Verso Books, London.
- **[R6]** Akshat Rathi (2023). Climate Capitalism: Winning the global race to zero emissions. John Murray Press, London.
- **[R7]** Lazard (2024). *Levelized Cost of Energy+ (LCOE+)*, June 2024. https://www.lazard.com/research-insights/levelized-cost-of-energyplus/

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"search opportunity" by Delwar Hossain, "search" by Uswa KDT, "idea" by Rusma Ratri Handini, "idea" by Atina Azka, "evaluation" by nicolas, concept" by Faridah, "analysis" by widphic, "wind turbine blade installation" by Sebastian Salomon, "regulation" by Wahicon, "revenue" by Rokhman Kharis, "profit" by Rasama studio, "sustainable energy" by Warhammer, "social impact" by gravisio, "risk" by miftakhudin, "wind energy" by baihaki, "solar energy" by Smalllike, "biomass energy" by Kamen Ginkaew, "equity" by Utami Febriarti, "debt" by Ali Romli, "electrolysis" by Designing hub", "energy storage" by Risk Ayu.