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Benoat Danglade
16/11/2022

Solaire Flottant

Centrale-Energies et Centrale Métiers de la mer – Webinaire
Système d'ancrage et cas d'étude aux Maldives

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Services

Specialist independent Marine Renewable Energies (MRE) multidisciplinary engineering and strategy advisory consultants.

- Flexible, comprehensive and dedicate engineering and design services
- **100% focus on MRE** in 5 key markets leveraging **leading R&D**

Providing services that cover the full development cycle of MRE technologies, Innosea supports developers and technology companies.

- >35 engineering specialists incl. PhDs and business consultants
- Dedicated Innosea teams in **Nantes, Barcelona and Edinburgh**
- Our values:
  - Safety leadership
  - Excellence and on-time delivery
  - Client's satisfaction & dedicated account management

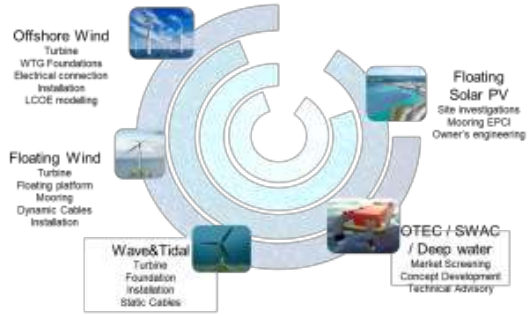
Renewables segments covered

Fixed OWFs

Floating OWFs

Floating Solar

Wave & Tidal



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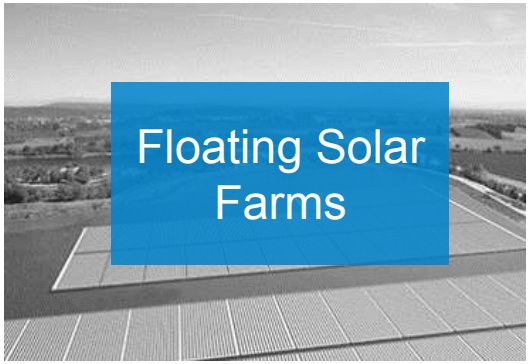
Experience Summarised

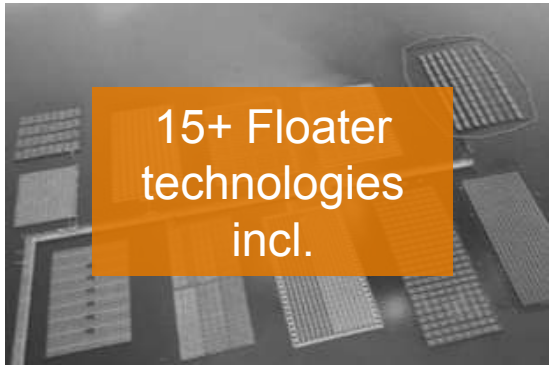


> **75** projects

> **1800** MWp

Since 2017

Indonesia	Maldives
Poland	Brazil
Taiwan	Portugal
France	USA
Seychelles	Laos
Afghanistan	India



Ciel & Terre	Ocean Sun
SunGrow	UpSolar
NRG Island	SunRise
Isifloating	Zimmermann
HelioRec	SolarInBlue
SolarDuck	etc.

- **Over 35 projects on dam reservoir / irrigation reservoirs** (> 1000 MWp cumulated)
- **25 projects on quarry lakes** (> 650 MWp cumulated)
- **6 projects in salty waters – offshore / nearshore / in tidal ports** (> 150 MWp cumulated)
- **4 European R&D projects** on the performance and reliability of FPV vs ground-mounted solar | Offshore floating solar
- **Support to technology developers** on numerical modelling and R&D topics

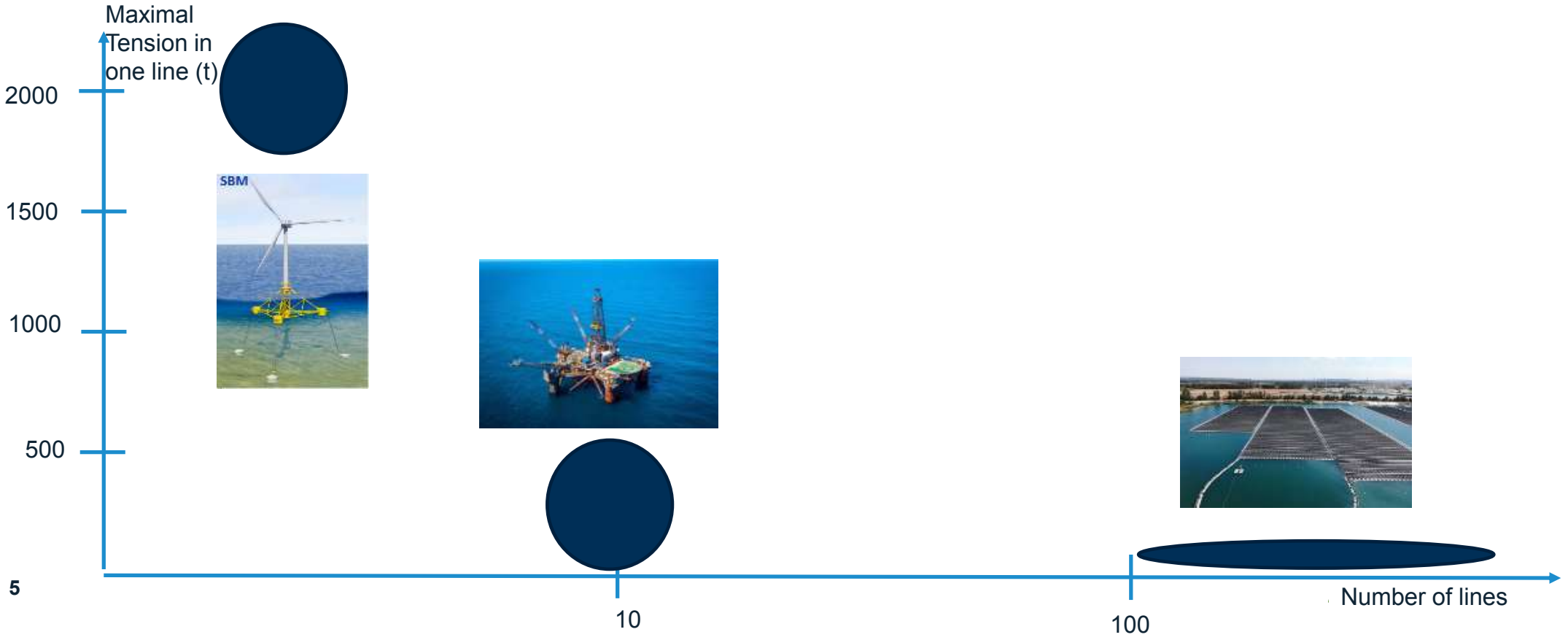
Systèmes d’ancrage

Introduction, Description, Conception

Offshore: Oil&Gas et énergies renouvelables + solaire flottant

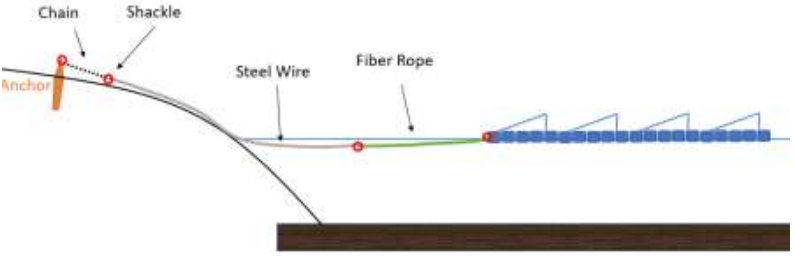
Deux options:

1. Redondance avec des lignes de taille réduite
2. Non redondance avec des lignes plus lourdes

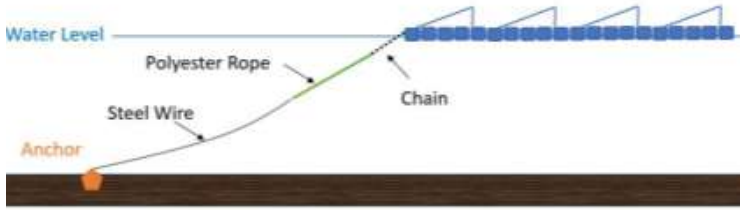


Conception du système d'ancrage – Revue technique

→ Ancres dans la berge

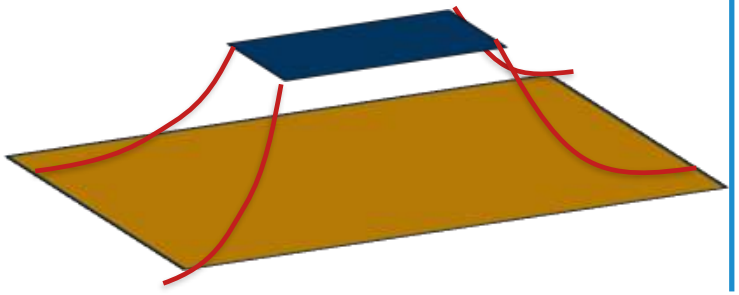


→ Ancres sur le fond

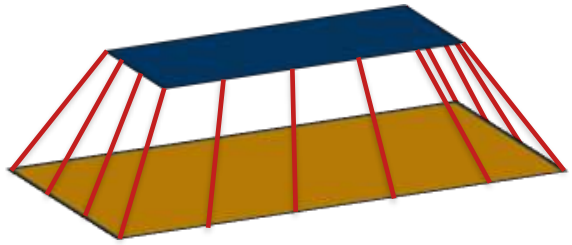


→ Système d'ancrage tendu

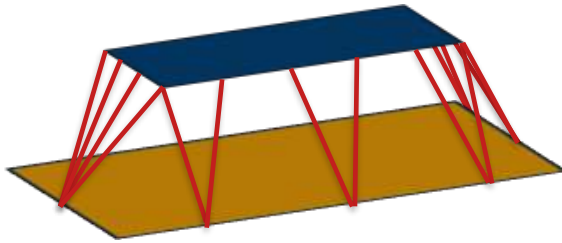
→ Système d'ancrage caténaire



→ Sans mutualisation



→ Avec mutualisation



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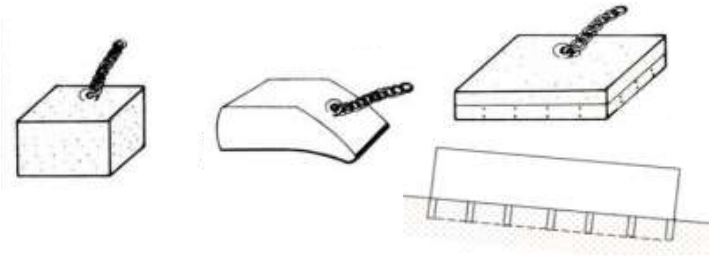
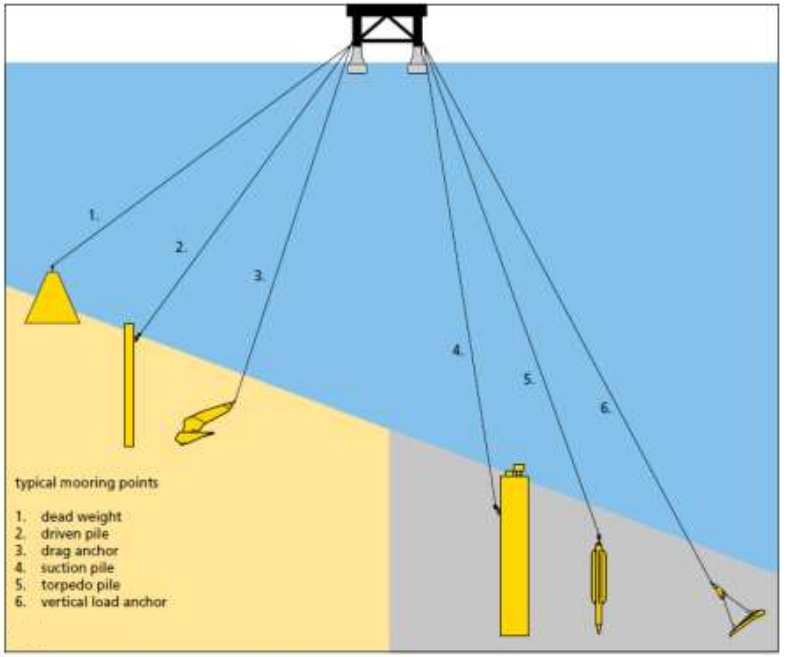
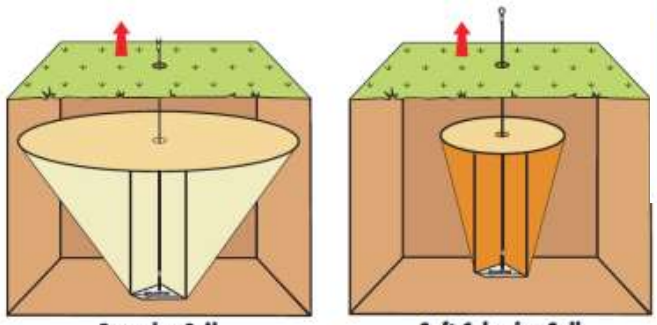
Conception d'un système d'ancrage – Ancres



Source: Fresher Project



Source: Vryhof Manual



Source: Platipus

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Revue des sites typiques

Petits plans d'eau (lacs de carrière, réservoir de traitement d'eaux usés, lacs naturels de petite taille) (~ 5-20MWp)

TRL 9: Prouvé à large échelle

Piolenc, France – Ciel&Terre technology (gauche) / Murcia, Espagne – Isifloating technology (droite).

Grands plans d'eau (lacs de barrage, grands réservoirs ou grands lacs naturels (~ 50-200MWp)

TRL 8: Mature et certifié

Huancheng Jinning, China – SunGrow technology (dessus) / Alto Rabagao, Portugal Ciel&Terre Technology (dessous)

Offshore /Nearshore Large/ Côtier

Démonstrateurs / prototypes

TRL 3-6: Démonstrateurs en operation
Preuve de faisabilité

Dutch North Sea (20 kW)
Oceans of Energy technology

Maldives (20kW), 4CSolar

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Systèmes d’ancrage : Paramètres de conception

Défis des systèmes d’ancrage:

Installation

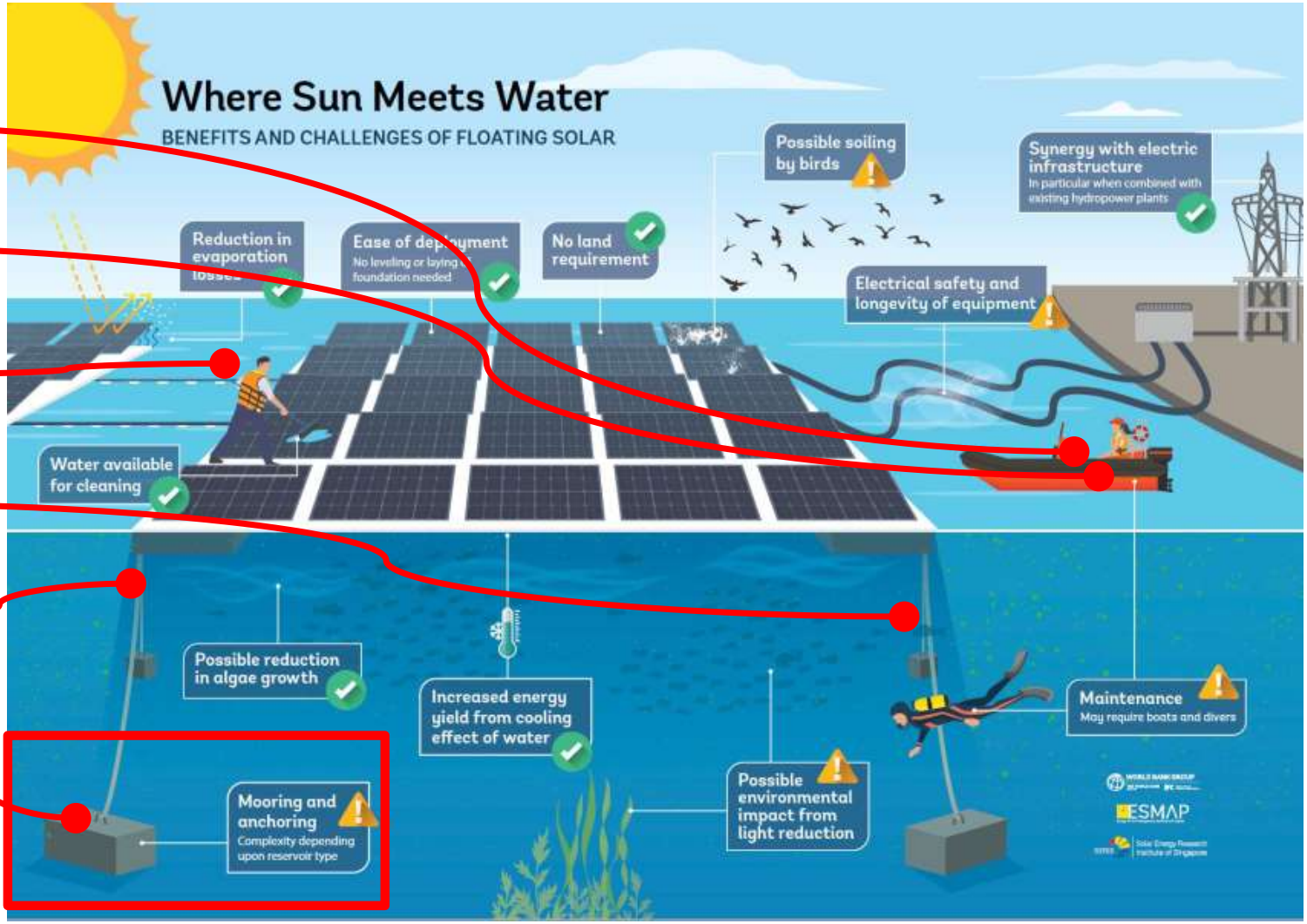
Opération et maintenance

Conditions environnementales (vagues, vent, courant, variation du niveau d’eau)

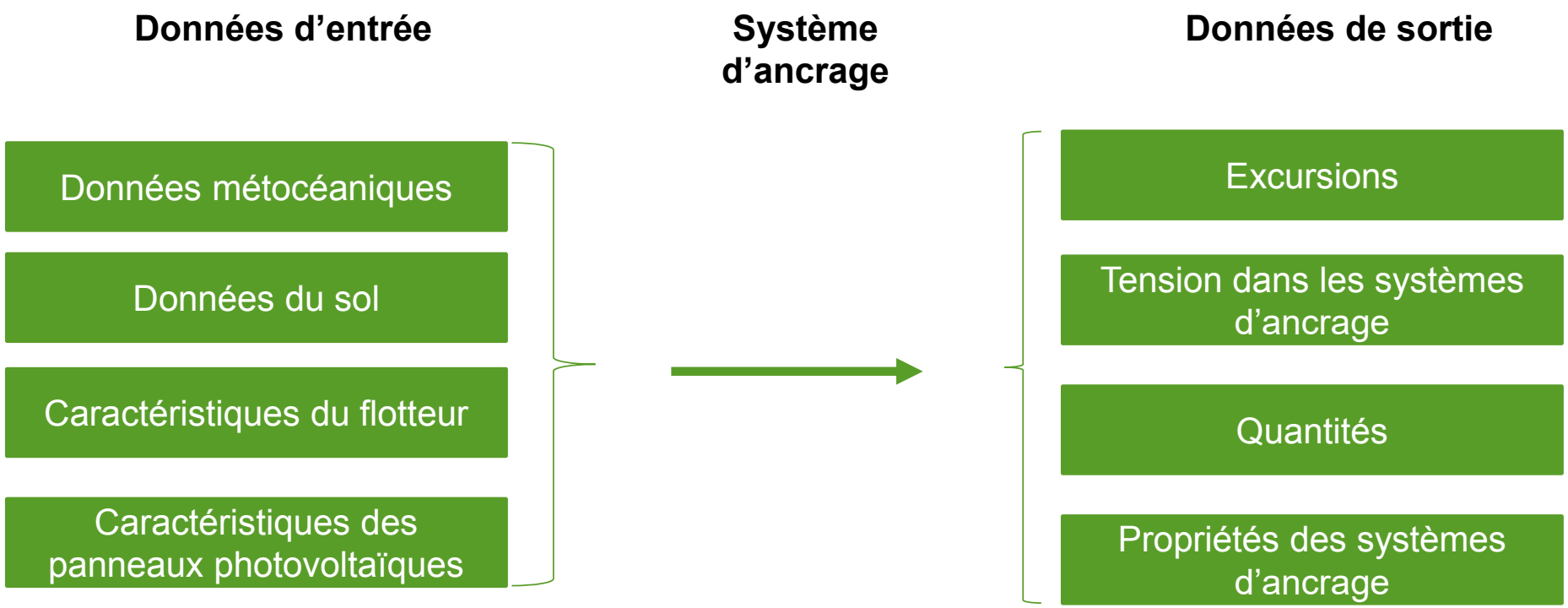
Types de lignes d’ancrage

Quantité des lignes d’ancrage

Sélection d’ancres



Systèmes d’ancrage : Paramètres de conception



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Cas d’étude

Zone insulaire – Lagon

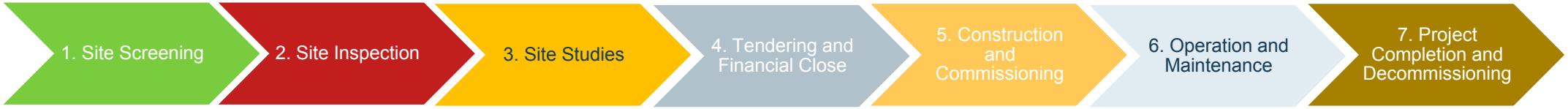
Reference Project
World Bank, Maldives

- ✓ Technical Advisory and site conditions specialist
- ✓ FPV project in atolls and lagoon

- ✓ Preliminary estimates of the potential for FPV in two regions of the archipelago
- ✓ Proposals on international best practices for FPV development
- ✓ Provide technical support to the World Bank during tendering process
- ✓ Coordination for the deployment of a 12-month site-specific data collection

Brief Project Details
Maldives
~10 MWp FPV
COD 2025

FPV Development Process : feasibility to RFP



Project Focus :

- Site screening
- Site studies and campaigns
- Financial Evaluation
  - Power Production Performance (Solar ressource assessment, losses, yield)
  - DEVEX, CAPEX OPEX, LCOE
  - Licences, Permits and Authorizations
  - Capital Sources
  - LCOE
- Best practises for nearshore deployment
- Redaction of Request For Proposal

Project Results:

- 3 sites selected: 1 MWp, 1MWp, 8MWp
- Design Basis
  - Water depth and water levels: 10-12 m
  - Waves: (Hs, Tp) = (1-1,5 m; 4-6 s)
  - Water temperature, Water current
- Need of specific vessels, panels, technologies
- Density of panels (1MW/Ha), distance to shore and grid
- RFP documentation for tender

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Site Screening

1. Site Screening | 2. Site Inspection | 3. Site Studies | 4. Tendering and Financial Close | 5. Construction and Commissioning | 6. Operation and Maintenance | 7. Project Completion and Decommissioning

- Identification of any red flags related to the site
- Largely be desktop-based

Main criteria:

- ✓ Topography
- ✓ Bathymetry
- ✓ Geology
- ✓ Hydrology
- ✓ Solar resource
- ✓ Infrastructure
- ✓ FPV Substation
- ✓ Grid access and Substation
- ✓ Environmental and Social

Each item is weighted depending on the impact they have on the suitability of the site

1. Identification of potential sites based on proximity of load centers

2. Shortlisting considering technical, E&S, grid-related, financial and meteorological constraints

3. Fatal flaw assessment, focusing on likelihood of occurrence

4. Selection of preferred sites

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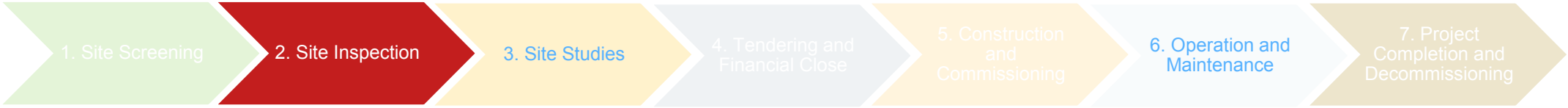
Site Inspection



- **Site visits** are necessary to verify the desktop-based observations done in the previous stage and meet stakeholders
- **Information collection on-site**: visual inspections, consultations with relevant stakeholders, drone footage, data samples, etc.
- **Social and local activities checks** : Ports expansion plans, maritime routes, tourism, development plans
- **Environmental checks** : protected areas, environment i.e., corals, seagrass, turtle and mammals

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Site Studies

1. Site Screening
2. Site Inspection
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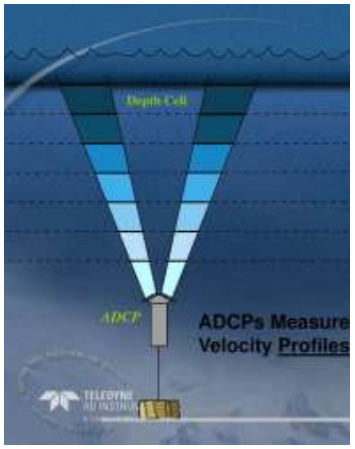

Minimum required information

Technical Information

- Wave height, period and direction
- Current speed and direction
- Water level variation
- Water depth estimation (low and high tide)
- Wind speed and direction at 10m
- Extreme events joint probability
- Soil properties (sediment type, moving with time, soil layers)
- Update of solar resource estimations

E&S Information

- Site surveys of seagrass / corals at sight, including categorization
- Water sample

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Introduction and Challenges

in the Development of Marine FPV

Challenges for marine FPV

Source: ClearWater Surf Travel

Source: PV-Magazine

Harsher environmental conditions:

- High salinity
- Stronger bio-fouling
- Higher dynamic loads by wind, waves, currents

Exposure to high biodiversity

Source: WorkingAbroad

Source: Anantara

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Technical Considerations

Beaching and water level variation

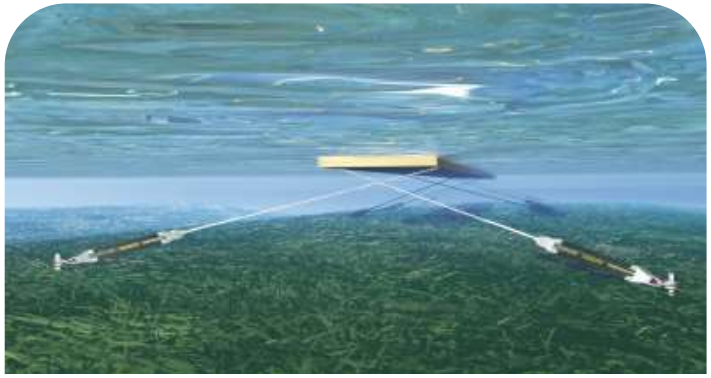
Source: Enerwhere

Partial beaching should be avoided

Shallow waters represent a risk of partial beaching at low tide, leading to uneven load distributions

No obstacles should be located beneath the system

Corals, reefs, ship/wreck, trees, etc. can harm the system, and vice-versa, therefore must be carefully considered during site selection



Source: Seaflex

Mooring and anchoring can be a major challenge

A system that can withstand the loads and simultaneously deal with shallow water and variation levels

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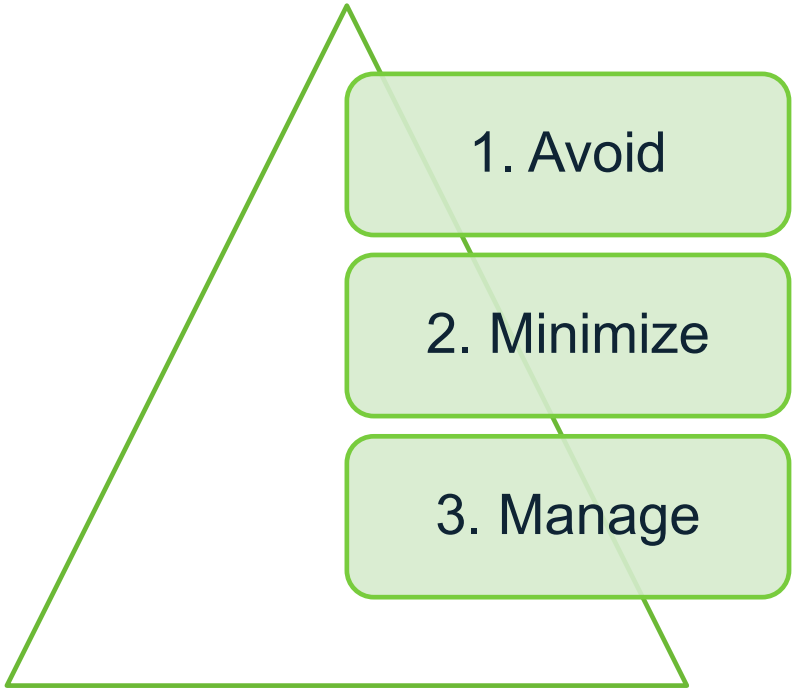
Environmental Considerations

Impacts could occur at every stage: installation, operation and decommissioning



Mitigation hierarchy of environmental impacts

+

Positive impact: FPV function as artificial reef, resulting in potential increase in species around the installation.

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Potential Impacts and Mitigation Measures : examples




POTENTIAL IMPACTS

- Blocked sunlight can have adverse impacts on corals and seagrasses
- Birds and other mammals could get entangled with the components
- Biofouling: affects the dissipation of heat from cables, enhances corrosion, and if extends to modules, can affect the performance
- Birds dropping causes shading on the modules, decreasing performance and requiring extra maintenance
- Mooring and anchoring fooprint could damage surroundings (contact with seabed, type of foundation)

MITIGATION SOLUTIONS

- Critical habitats, protected areas, sites of natural/cultural/social significance must be avoided
- Buffer zones must be maintained around protected areas
- Ecological anchors should be used to reduce unwanted interactions with the ecosystem
- Anti-fouling coating (but it can also affect the biodiversity)
- Choice of dynamic mooring lines




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