

***EDF Renewables pathway to  
commercial-scale floating wind farms***



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# EDF Renewables (“EDFR”) : a leader in Offshore Wind

*1st wind farm commissioned in 2009 in Belgium*



**1.1**

gross GW commissioned

*Experienced in both fixed and floating wind*



**>2**

gross GW under construction

*Technical & industrial capabilities from early development to in-house maintenance*



**600+**

Offshore Wind staff



**>6**

GW in development



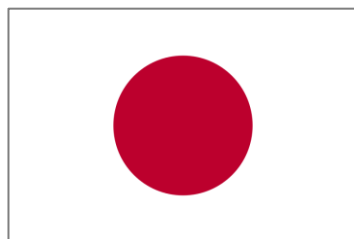
**>20**

Offshore wind Projects in portfolio



**15**

Countries with developments



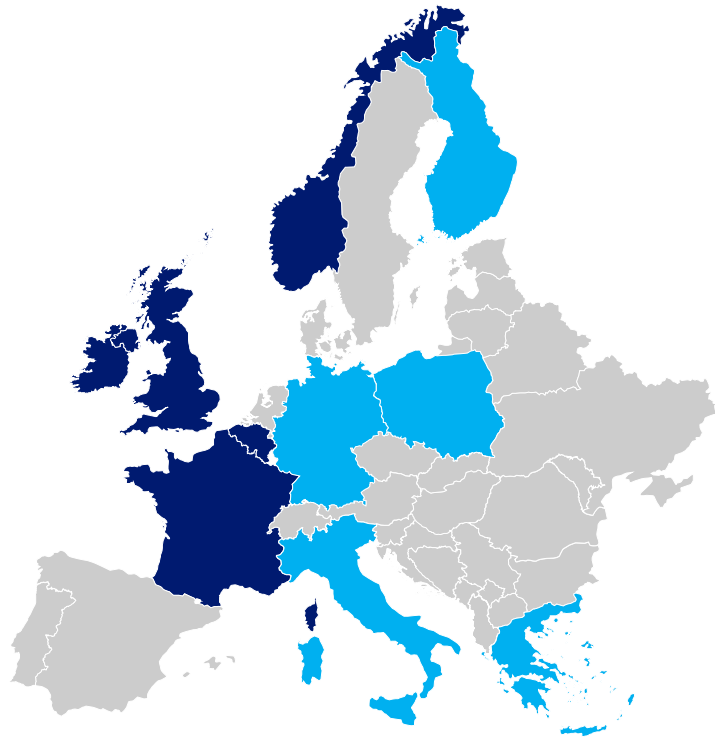
## EDF Renewables in Japan

- Strong historical relationship with main Japanese energy players in Nuclear field
- Local subsidiary named EDFR Japan K.K. is under incorporation, to be created in June 2022
- Local team to be based in Tokyo office, start of local activities in Q3-22
- **We are looking for long-term strategic Japanese partners:**
  - to support development of wind offshore Business
  - propose solutions for green H<sup>2</sup>/Ammonia projects

# EDFR currently operates >1GW offshore wind, with strong development plan

*EDF Renewables has a worldwide offshore wind footprint, Japan to be one of the leading country for offshore wind activities*

Europe



Asia





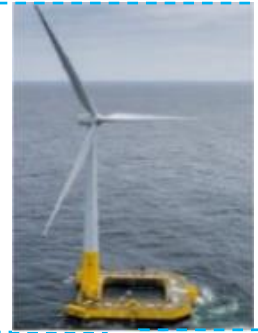
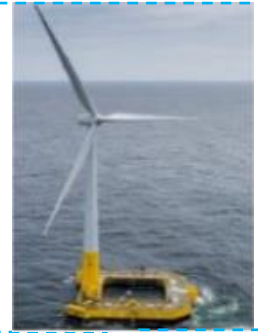
Americas

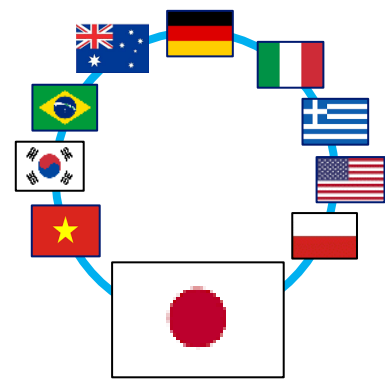


■ EDFR presence in offshore wind    ■ Ongoing developments, EDFR local presence

# EDFR Floating Offshore Wind projects, the learning curve

EDFR works on a diversified projects portfolio (geographies, technical spec., foundations) to build-up a 360° internal knowledge

TLP	Semi-sub	Concrete barge	
 <p><b>25 MW</b> PROJECT PGL France Foundations : tension-leg Water depth : 100 m COD : 2023</p> <p><i>Pilot project</i></p>	 <p><b>50 MW</b> PROJECT BLYTH 2 United Kingdom Foundations : semi-sub Water depth: 52-58 m COD : 2026 (est.)</p> <p><i>Pilot project</i></p>	 <p><b>250 MW</b> AO5 BRETAGNE SUD France Water depth: 100m COD : 2031 (est.)</p>	 <p><b>2x 500 MW</b> AO6 Mediterranean Sea France Water depth: 80 to 110m COD : 2032-2033 (est.)</p>



Japan is a strategic country for EDFR



<p><b>Up to 1GW</b> PROJECT UTSIRA NORD Norway Water depth: 200-300m COD : 2028 (est.)</p>	<p><b>Up to 4.5GW</b> CALIFORNIA LEASE USA Water depth: 750-1100m COD : 2032 (est.)</p>	<p><b>Up to 1 GW</b> PROJECT OCEAN HARVEST Taiwan Water depth: 75m COD : 2029 (est.)</p>	<p><b>Up to 1 GW</b> PROJECT GWYNT GLAS United Kingdom Water depth: 70-100m COD : 2031 (est.)</p>
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# EDFR developed in-house innovative methodologies & robust tools

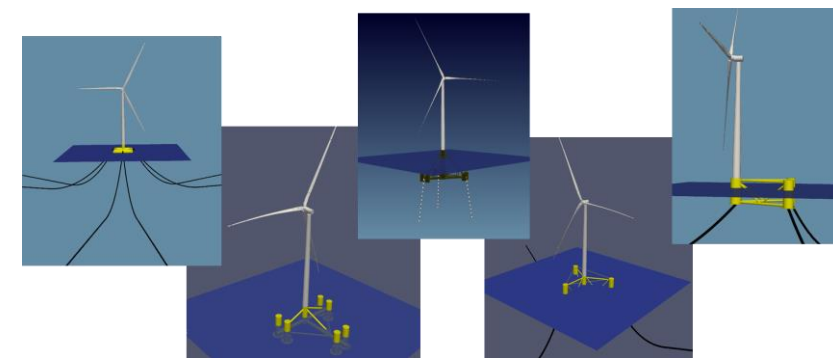
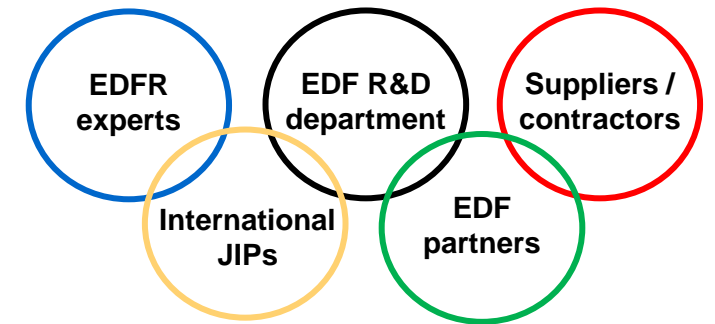
*EDFR aims to reduce the industrial risks of offshore wind projects through a substantial and long-term R&D program*

## R&D projects and JIPs

- ✓ **The Floating Wind Joint Industry (FLW – Carbon Trust):** International initiative that aims to overcome the challenges and investigate opportunities for the deployment of large-scale commercial floating wind farms (subjects: electrical systems/mooring systems/logistic/WTG and foundation optimization/asset integrity)
- ✓ **Center of excellence floating wind JIP (ORE CATAPULT):** Drive the commercialization of floating offshore wind for the UK's benefit
- ✓ **OMDYN<sub>2</sub> (FEM) :** Dynamic cables for marine energy (experimental and numerical modelization of constraints)
- ✓ **MUTANC (FEM):** MUtualized ANChors for offshore wind farm
- ✓ Examples of **internal research topics:**
  - ❑ Impact of floater motions on AEP
  - ❑ Marine growth aleter algorithm
  - ❑ Weather stand-by assessment for a selection of floating wind turbine at sea assembly scenarios off California

## DIEGO: example of EDFR internal tools

- ✓ **DIEGO is an Aero-Hydro-Servo-Elastic Solver dedicated to Offshore Wind Turbines** developed since 2012 by EDF
- ✓ Evaluation of key indicators including power generating efficiency and reliability of OWT structures under different circumstances (regular/extreme, environmental/servo, etc..)
  - ❑ **Allows EDFR to run autonomous validation procedures** when different design & concepts are proposed by external suppliers
  - ❑ **Provides EDFR's decision-makers with more reliable technical contexts** when considering the selection of turbine/floater suppliers
  - ❑ **Will allow EDFR to consider new concepts and/or new technical functionalities (e.g, twin rotors )**

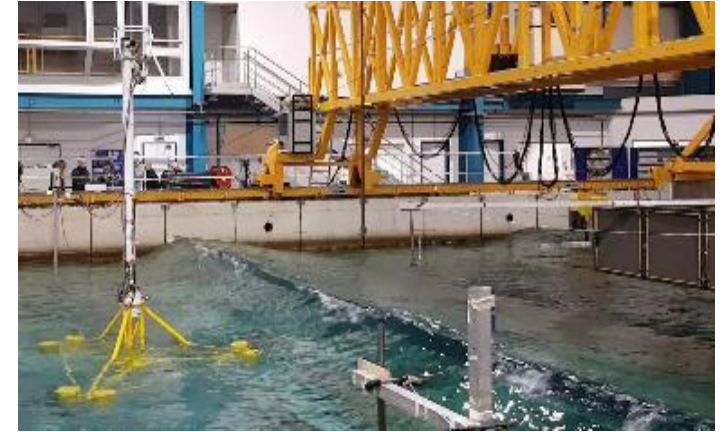
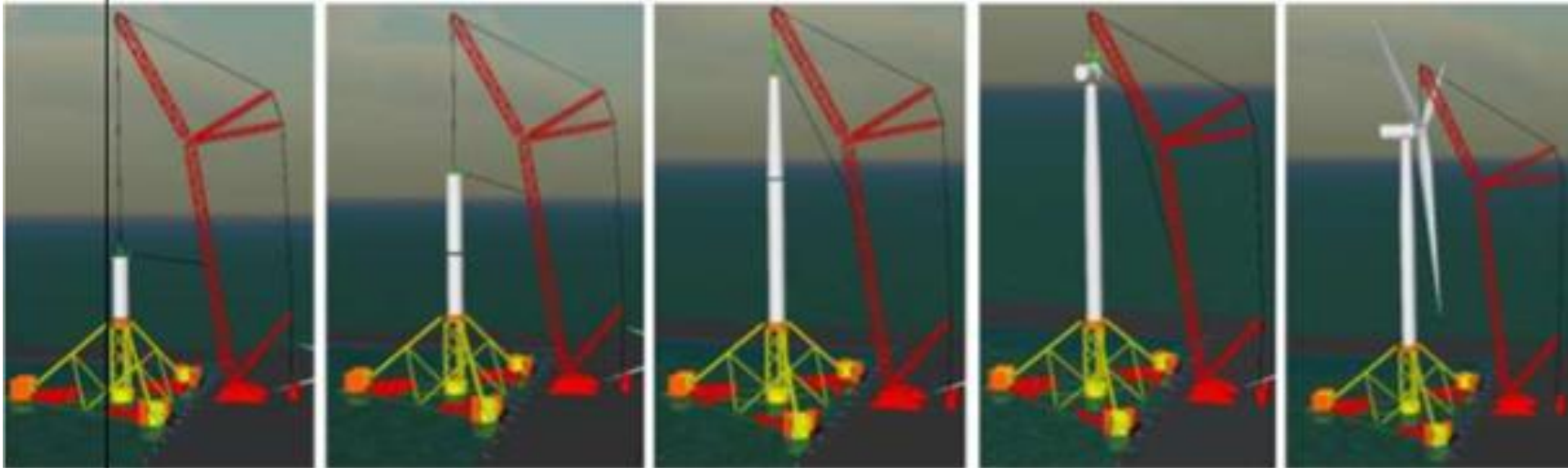


*Floating systems virtual simulation*

# Challenges are known and being solved for pilot farms

## Key topics for floating wind design

- ✓ Combined and dynamic effects of wind, waves and current on the system (moorings, floater, cable, turbine) need to be accounted for with **coupled numerical simulations**, in order to secure **turbine performance on a floating body**. A dedicated tool has been successfully developed over the last 8 years by EDF R&D to capture these couplings.
- ✓ **Mooring system** design: large variety of solutions from O&G industry, depending on soil and floater type
- ✓ **Inter-array electrical cables** long term integrity (dynamic configuration)
- ✓ **Installation of the turbine on the floater at quayside**



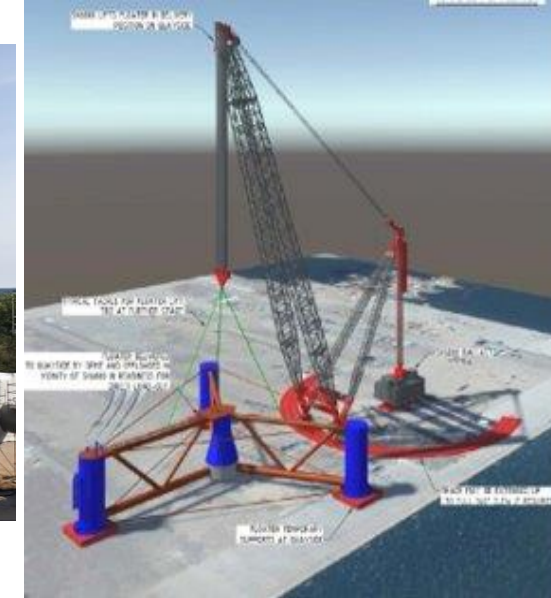
# At commercial scale, new solutions are required

## Large scale industrial process needed to reach an acceptable LCOE

- ✓ Overall, **reaching LCOE in the ranges obtained by other renewable technologies is still a challenge** : current values a bit less than 100 €/MWh for large scale plants, excluding grid connection.
- ✓ **Validate use of large (20+MW) turbine** for floating (challenging tower design)
- ✓ **Mooring system safety factors** and redundancy to be challenged, investigate anchors mutualization and mooring line new materials
- ✓ **Fabrication, launching, towing and hook-up of 20 to 60 floaters** of 5000 to 15000t each: develop robust execution plans (quality control, reduction of assembly duration at quay, reduction of the number of welds on the critical path,...)

## Logistics, technical and consent challenges

- ✓ **Liaise with port authorities** to identify long term requirements of the industry (lifting cranes, quay length, water depth at quay,...).
- ✓ **Inter-array cables** to develop quick connection/disconnection devices for installation and O&M
- ✓ **O&M: avoid tow-back** to port for major repairs.
- ✓ **Co-activity with fisheries**
- ✓ **Continuous discussions with local authorities and environmental organizations**



# Main challenges for the floating offshore wind in Japan

*Demonstration projects have paved the way for the 1<sup>st</sup> generation of commercial-scale floating wind farms*



Towards a Floating Offshore  
Wind Industry in Japan

## What EDFR could bring to its Japanese partners

- ✓ Experience and lessons learnt from constructions/operations and maintenance
- ✓ Experience from development and construction phases of PGL
- ✓ Technical expertise, assessment and selection of the best suitable combination of technology (WTG, Floater, Anchoring,...)
- ✓ Cooperation on a demonstrator floating wind project
- ✓ O&M optimisation

## What EDFR would rely on from its Japanese partners (not limited to)

- ✓ Stakeholder engagements (local governments, fisheries, local residents, etc.)
- ✓ Community outreach and economic contribution to local/Japanese economy
- ✓ Grid connection knowledge
- ✓ Local supply chain build-up
- ✓ Ports and vessels logistics
- ✓ Experience in certification processes



# Thank you !

May 2022: **on time delivery** of all foundations at Saint-Nazaire Offshore Wind Farm, the **1<sup>st</sup> French Offshore Wind Farm** (80 monopile foundations with a 7.7 m diameter installed on a calcarenite bank).



Saint-Nazaire Offshore Wind Farm is the **1<sup>st</sup> in the world to use mechanized drilling** for the construction of large-diameter monopile foundations.



May 2022: PGL assembly yard, **1<sup>st</sup> Floating wind farm in construction in France**





# Additional information

# Case study : Provence Grand Large (“PGL”) project, France

*Provence Grand Large has paved the way for the 1<sup>st</sup> generation of commercial-scale floating wind farms*

## Project characteristics and history

- ✓ **PGL is a floating wind project developed from the start by EDF Renewables**, composed by 3 wind turbines of a unitary capacity of 8MW, and design based on tension-leg foundations
- ✓ **It will be one of the 1<sup>st</sup> pre-commercial size floating array**, the 1<sup>st</sup> installed project in France (COD expected by end 2023)
- ✓ **An aggressive bid strategy in several types of sites**, with detailed collaboration with 5 promising floaters types
- ✓ **An associated deep understanding of floater design drivers and in-house turbine/floater hydro-mechanical analyses capabilities** (DIEGO platform from EDF R&D started 8yr ago)
- ✓ **Design, innovation and construction** : overcoming multiple innovation challenges made PGL a remarkable teaching tool for the internal team who has proven to be very agile in order to find solutions for this still emerging technology
- ✓ **Financing** : this 1<sup>st</sup> floating project financed by commercial banks opens the way for the next generation and larger scale projects in France, Europe and worldwide

## 1<sup>st</sup> lessons learned on construction of a floating offshore wind farm

- ✓ **Critical lifting operations suppose to have a dedicated area in harbor**
  - ❑ Adapted quay with adequate loads capacity and water depth, maximal tension bollards characterization
  - ❑ Management of co-activities risks with other harbor operators/stakeholders.
- ✓ **Current nacelles design need to be adapted to floating conditions**
  - ❑ Today the nacelles used for floating projects are identical to fixed-bottom projects
  - ❑ For floating projects, the lower part of the nacelle (material, reinforced structures,...) should be adapted in order to facilitate its assembly with the tower top due to possible floater motions



# Thanks to its offshore wind experience, EDFR has best-in-class competencies and competitive advantages to be a top market player



-  R&D
-  Worldwide footprint
-  Development skills
-  Fishing industry cooperation
-  French market build-up
-  Construction experience
-  O&M capabilities
-  Early mover on Floating
-  Financing

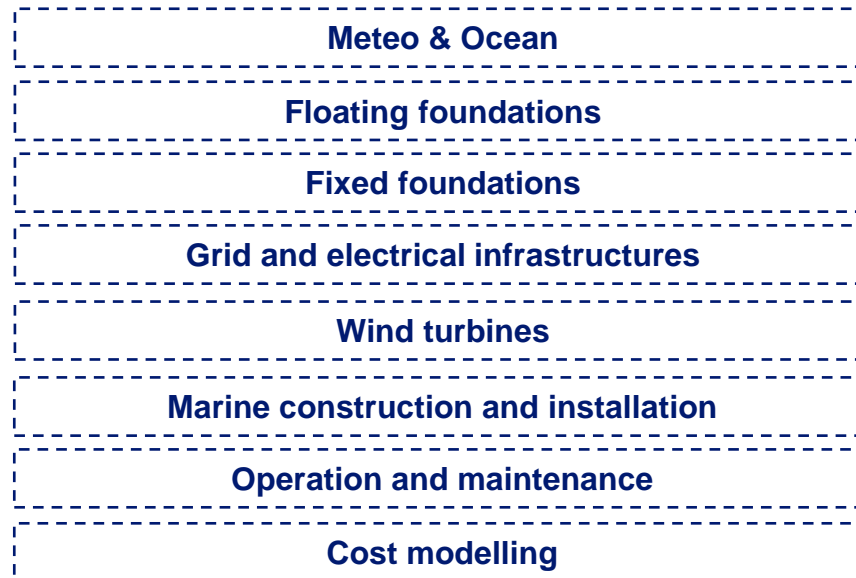
# Interaction with EDF R&D

## EDF R&D key figures

- €700 million annual budget
- 2000+ people
- 2000+ patents
- 9 centers worldwide
- 300+ partnerships with the industry
- 70 testing facilities
- 11 petaflops of calculation capacity

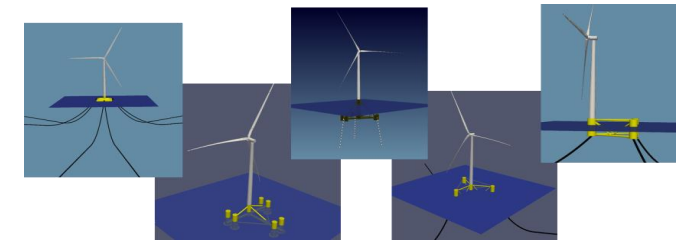
## A dedicated program for EDFR Offshore Wind

### 8 workstreams

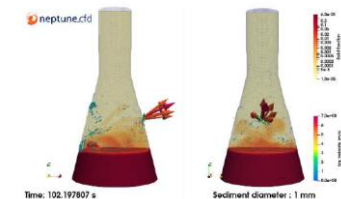


## In-house tools developed by EDF R&D for EDFR business

- Fully coupled analysis of floating systems
- Pre-design of fixed foundations
- O&M execution plan & cost
- Anticipation of offshore wind cost evolution



Floating systems virtual simulation

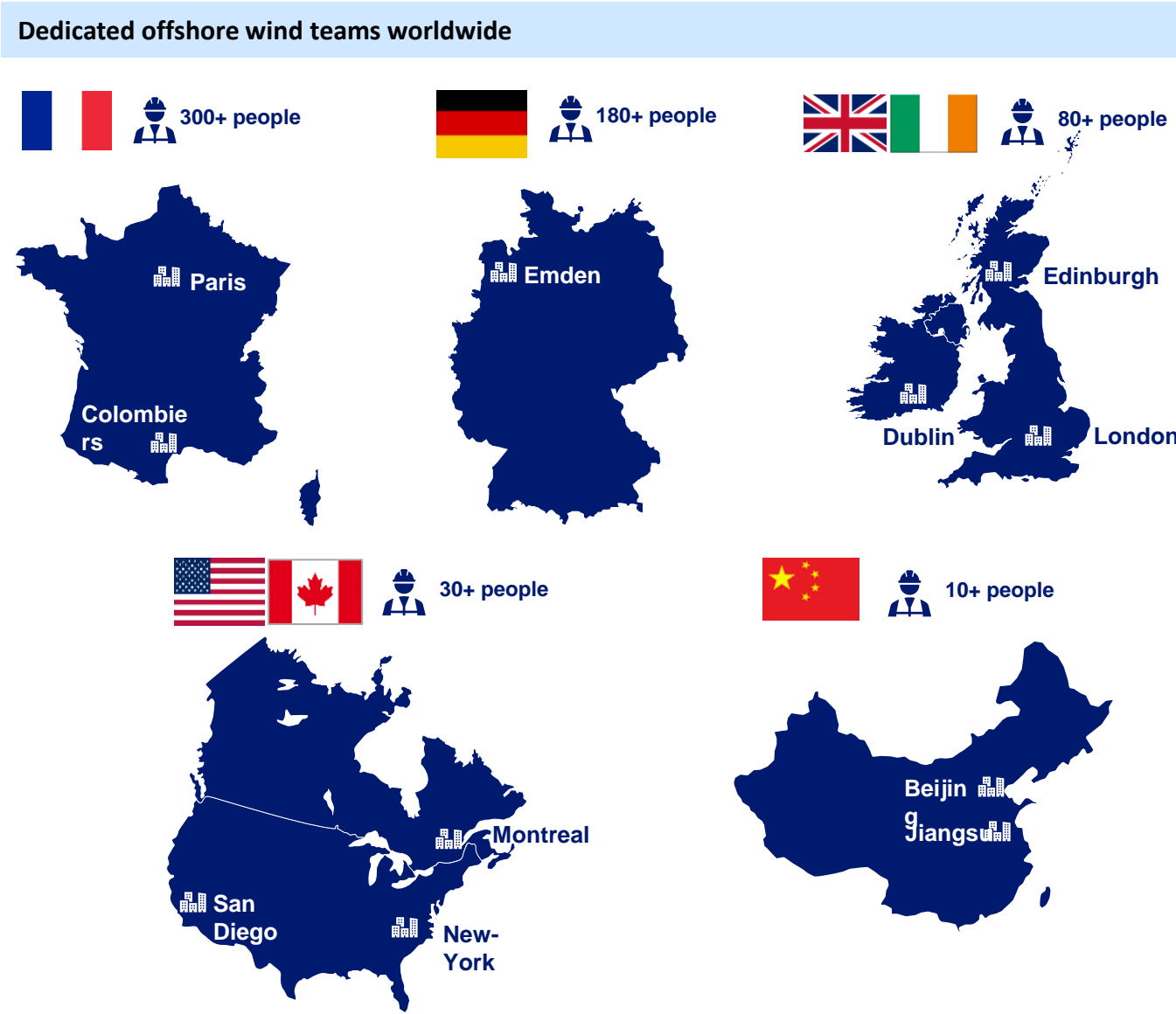
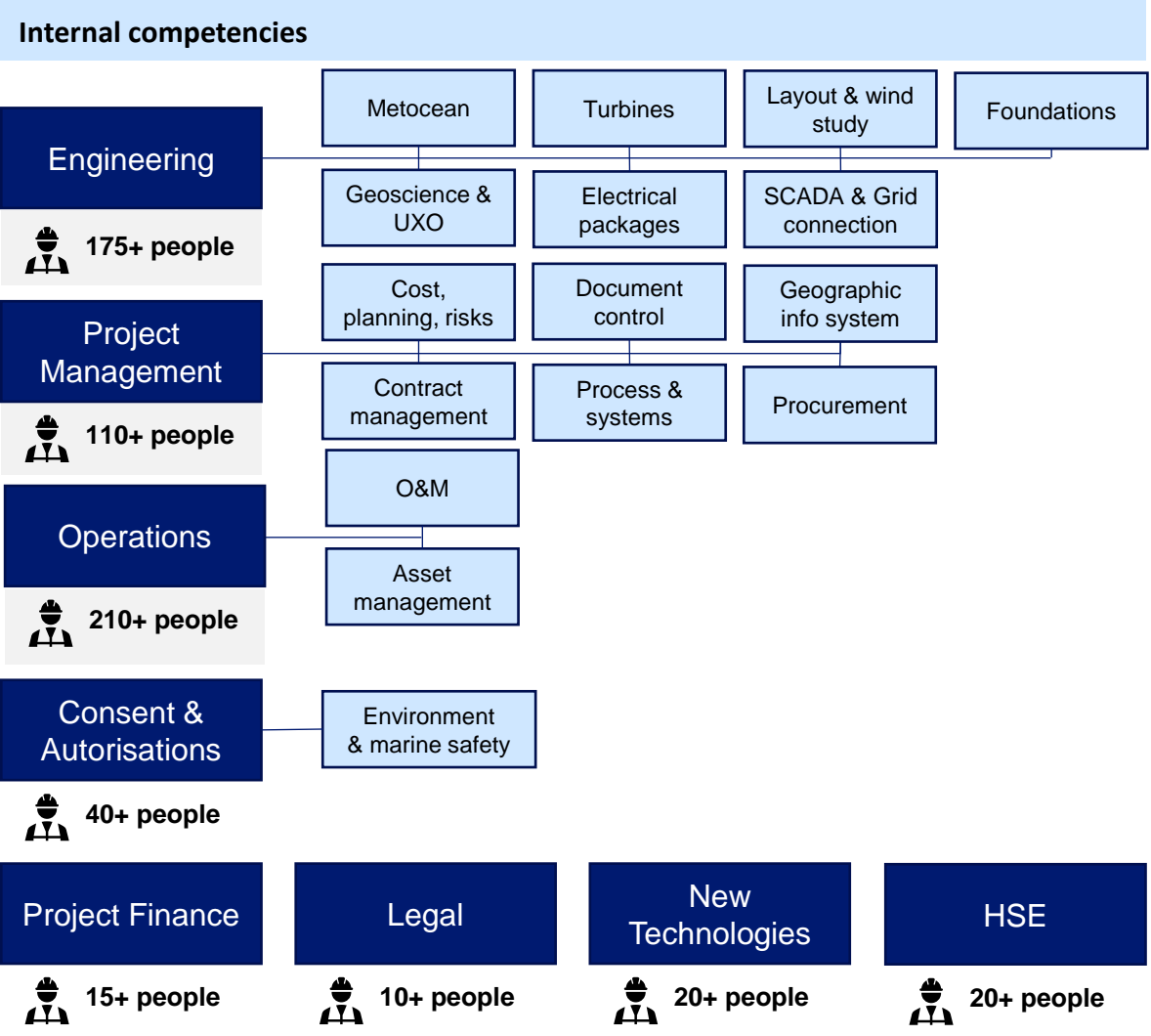


Sediment simulation



*EDF R&D support to on-going developments and projects to solve specific issues or challenge selected solutions*

# EDF Renewables Offshore team worldwide : 600+ people



# Selected internal Offshore Wind experts



## **ENVIRONMENT - Jean Philippe Pagot, Head of Environmental team**

- Over 28 years of experience in marine environment and impact assessment,
- Field of expertise ; marine ecology, marine mammals, water quality, benthic habitats, marine safety, fisheries et fish resources. Environmental regulation
- Experience : Cousteau Teams (NGO), Chairman at FEM (French national institute for energetical transition dedicate to Marine Renewable)



## **PROJECT DEVELOPMENT - Nancy McLean, PhD, Senior Development Manager**

- Over 18 years of delivery of renewables' permitting activities across a variety of geographies,
- Field of expertise across all phases of the offshore wind life cycle
- Experience: Involvement in strategic Government led groups to address national scale barriers to consenting of offshore wind, and expertise in prioritising complex, interacting engineering constraints and environmental mitigations.



## **FLOATING WIND - Christine de Jouët, Provence Grand Large (PGL) Director**

- 12 years of experience in offshore wind industry, including 7 as loads department Head for WTG/foundations design and 5 as Floating project Director
- 15 years' experience in Naval Hydrodynamics (PhD in fluid dynamics )
- Experience: Project Management, offshore Wind tenders, Turbines' roadmap, Floaters technologies, Value engineering, Development of R&D programs



## **UNEXPLODED ORDONANCE (UXO)- Benoît Jouy, Maritime Risks Expert**

- 10 years experience in offshore wind,
- UXO Strategy, UXO Risk Assessment and mitigation, UXO Survey, UXO data Proofreading and classification, ROV and Diving survey, Removal survey.
- Formerly spend more than 20 years as clearance diver (MCM forces), then held positions as safety manager



## **FLOATING WIND - Steve Hegarty - Blyth II Engineering Manager**

- Over 25 years with delivery offshore projects worldwide in all project phases,
- Leading delivery of engineering on billion dollar projects specialising in floating and subsea systems,
- Experience in fixed and floating wind and development of offshore operations from shallow to ultra deep water and many first of kind works.



## **PROCUREMENT – Yasmine Yurdusev, Head of Offshore Wind Procurement**

- 15 years experiences with 13 years mainly in the offshore wind and Oil & Gas industry
- Procurement Management from the needs definition up to the contracting phase in challenging technical & international environments
- Skills: Sourcing strategy, negotiation, strong interpersonal skills, Turbine and T&I category management, Global Strategic Key Account Management



## **WIND, LAYOUT, METOCEAN, TURBINE - Benoit Clauzet, Head of Offshore Wind & Site**

- 15 years' experience in wind Industry, 12 of which were in offshore wind
- Experience: Yield manager, Concept & Layout manager, Engineering manager.
- Skills: In-situ measurement, Design Basis, Energy Yield Assessment, Layout optimization, Turbine's roadmap, Value Engineering, Project Optimization.



## **GEOTECHNICAL - Hong Doan, PhD, Senior Engineer**

- 14 years of experience in geotechnical engineering and foundation installation activity,
- skills: site characterization, laboratory testing, foundation design and advanced numerical analysis
- Experience: IFPEN (research in energy), Fugro (geotech contractor), Subsea 7 (EPCI contractor)
- Vietnamese representative at "offshore geotechnical" international committee

# Green hydrogen, a growing experience within EDF

## An efficient organization within the group for green hydrogen

*EDF has already mobilized a clear organization to launch green hydrogen projects worldwide and to gain market share as an integrated player*



### Develop green hydrogen projects worldwide.

- N°1 in Europe for renewable energy generation
- Core business: develop competitive renewable energy, adapted to timeline and sites
- Efficient internal organization with both experts and local teams



### Develop low carbon hydrogen projects in France and Europe, since 2019.

- Industry and mobility projects
- H2 production by electrolysis of water, distribution and commercialization
- All-in-one solution (project development, financing, construction, O&M)
- Electrolyzer expertise and 1<sup>st</sup> project operational in 2021.



### Support the group's entities to develop green hydrogen projects

- State-of-the-art expertise
- Pilot projects
- International presence



## Already operational projects developed by the group

### A mobility project in France 1 MW already in operation in Auxerre 2021



- **1 MW** station (3MW in 2025)
- **400 kg** of hydrogen/day (1200 kg/day in 2025)
- **100%** alimented by renewable energy
- **5 municipal buses** (+4 in 2025)
- An **H2 train** (in 2025)

### An industrial project in Germany



- **30MW** in 2023 to **500MW** in 2025 and **2.1GW** by 2030
- **Objective** : Replace grey hydrogen for a refinery plant and create a production hub with methanol and kerosene
- **Transport** : part of green H2 to be transported via a dedicated hydrogen pipeline
- **Joint venture** consisting of Hynamics, Ørsted, and the Heide Refinery (first phase –30 MW). 10 partners in total within the “Westküste 100” will also work on a phase 2 with a multiple GW electrolyzer.





# Offshore Wind & Hydrogen : 1st project for EDFR in UK



- ✓ EDF Renewables UK and Hynamics, a subsidiary of EDF Group specializing in hydrogen, have revealed plans to invest in a green hydrogen production centre in the vicinity of the former Redcar steelworks.
- ✓ Tees Green Hydrogen, will be a pioneering project, using the green electricity from nearby Teesside Offshore Wind Farm along with a new solar farm, which EDF Renewables UK intends to construct near Redcar, to power its hydrogen electrolyser. The project will supply local business customers with hydrogen to support decarbonization efforts and a significant reduction in industrial pollution.
- ✓ The initiative was announced at Teesworks with British Steel Lackenby and PD Ports.
- ✓ In October last year, British Steel unveiled its Low-Carbon Roadmap, which sets out its plans to, among other solutions, develop the application of hydrogen in its operations.
- ✓ Arrangements have already been made to supply PD Ports with hydrogen to decarbonise port operations and will further explore maritime decarbonisation more widely.
- ✓ In its initial phase, the electrolyser will be 30-50MW in size, but is designed to be able to scale to over 500MW, in line with emerging demand.
- ✓ Detailed plans for Tees Green Hydrogen will be released later this year, with a consultation on the 49.9 MW Tees solar development taking place later this month. The solar and hydrogen initiatives will add to EDF's already considerable presence on Teesside, which includes its offshore wind farm at Redcar, operational since 2014 and nuclear power station in Hartlepool which has supplied low-carbon electricity for nearly 40 years.

# The Green Fuel Alliance project in Egypt

*The Green Fuel Alliance, led by EDF Renewables, is planning to develop in Egypt a 350,000 tons per year green ammonia facility to be used as bunkering fuel to service the Suez Canal maritime traffic*



- ✓ The consortium Green Fuel Alliance is led by EDF Renewables, a global player in renewable energy, and the UAE-based Zero Waste, a company specialized in developing projects in the Egyptian oil & gas, and power generation industries.
- ✓ The consortium signed a memorandum of understanding (MoU) with the Egyptian New and Renewable Energy Authority (NREA), the Egyptian Electricity Transmission Company (EETC), the General Authority for Suez Canal Economic Zone (SCZONE), and the Sovereign Fund of Egypt (TSFE) for cooperation on joint development of green hydrogen and green ammonia mega-project at the Suez Canal Economic Zone (SCZONE).
- ✓ The MoU is to elevate the strategic partnership between the two entities and accelerate the timeline of the maritime industry; to reach net-zero emissions by securing carbon-free fuel for ships, vessels, and tankers crossing one of the most strategic global waterways – the Suez Canal.
- ✓ This collaboration is part of the Ministry of Electricity, the SCZONE, and TSFE's commitment to diversifying Egypt's energy mix. The emphasis is on increasing the reliance on renewable energy, green hydrogen, and downstream green ammonia production.
- ✓ The Green Fuel Alliance is planning to develop a 350,000 t/y green ammonia facility to be used as bunkering fuel to service the Suez Canal maritime traffic.
- ✓ The 1<sup>st</sup> phase of the project is to be operational in 2026, with the 2<sup>nd</sup> phase expansion to be fully operational by 2030.
- ✓ In addition, the consortium is planning to build 650 MW of renewable energy "Solar PV and Wind" to power the ammonia production facility with green energy

# EDF Battery Storage Plan: 10GW in 2035

## 1. Grid energy storage



Worldwide

## 2. Customers



Europe and USA

## 3. Access to electricity



1.2 million customers

Sub-Saharan Africa

Investment of  
€8 billion  
(deconsolidated)

€70M  
R&D  
between  
2018 and  
2020  
  
X2

€15M  
invested  
in start-  
ups

## One of the group's major projects: West Burton, UK

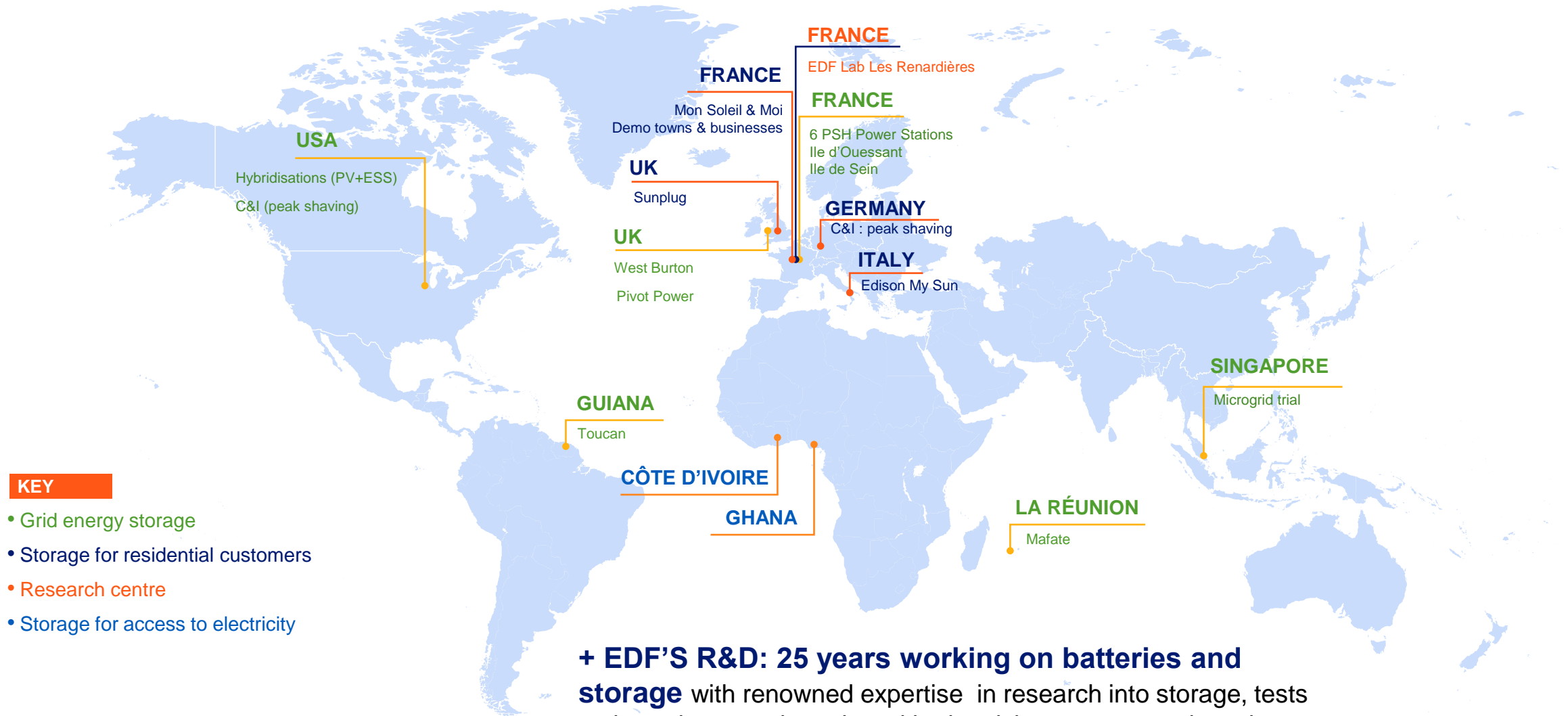
EDF is a pioneer when it comes to stationary storage with batteries



Largest storage unit set up by EDF in the UK (49MW)  
Capacity agreement and frequency response contract  
with the National Grid as of 2018



# EDF Battery Storage Plan: involved in projects across 4 continents



**+ EDF'S R&D: 25 years working on batteries and storage** with renowned expertise in research into storage, tests on batteries experimenting with electricity systems, and much more