FZK Forschungszentrum Küste

14. FZK Kolloquium

Marine Ressourcen und Erneuerbare Energien
21. Apr. 2019, LUH&TUBS, Hannover

Recent Developments on GWK*plus**

- Concept, Technical Design and Performance

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Technische Universität Braunschweig

(3) FZK Forschungszentrum Küste

*GWKplus is part of marTech granted with the support of the Fed. Min. for Economic Affairs and Energy (BMWi) with funding number 0324196A-B, 2017-21

Federal Ministry for Economic Affairs and Energy

Wind park Veja Mate, German Bight, Northsea:

95 km NE Borkum, depth: 41 m, installed power:
402 MW (67 x 6 MW), length/diameter of monopiles: 82.2m/7.2m

"(...) global transformation of energy systems (...) is technically feasible and economically viable..."
► *focus on reliability of technologies over life cycle*

Flagship report 2011 – "World in Transition – A Social Contract for Sustainability"
German Advisory Council on Global Change (WBGU)

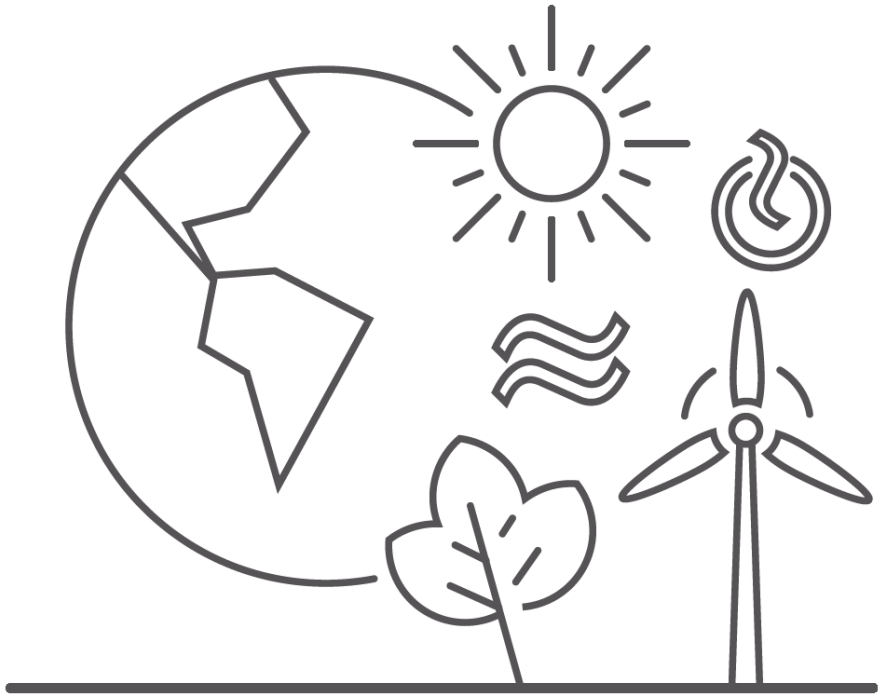
German Offshore Wind targets (BMWi, 2015):
- 6.5 GW (2020) and 15 GW (2030)

Yet, installed and in operation: 5.4 GW (by end of 2017)
- 1st half 2018: ~0.40 GW (completed)
- 2nd half 2018: 0.75 GW (expected)

► German targets may be accomplished earlier!

"(...) to meet the 1.5°C goal include ramping up the installation of renewable-energy systems to provide 70–85% of the world's electricity by 2050.

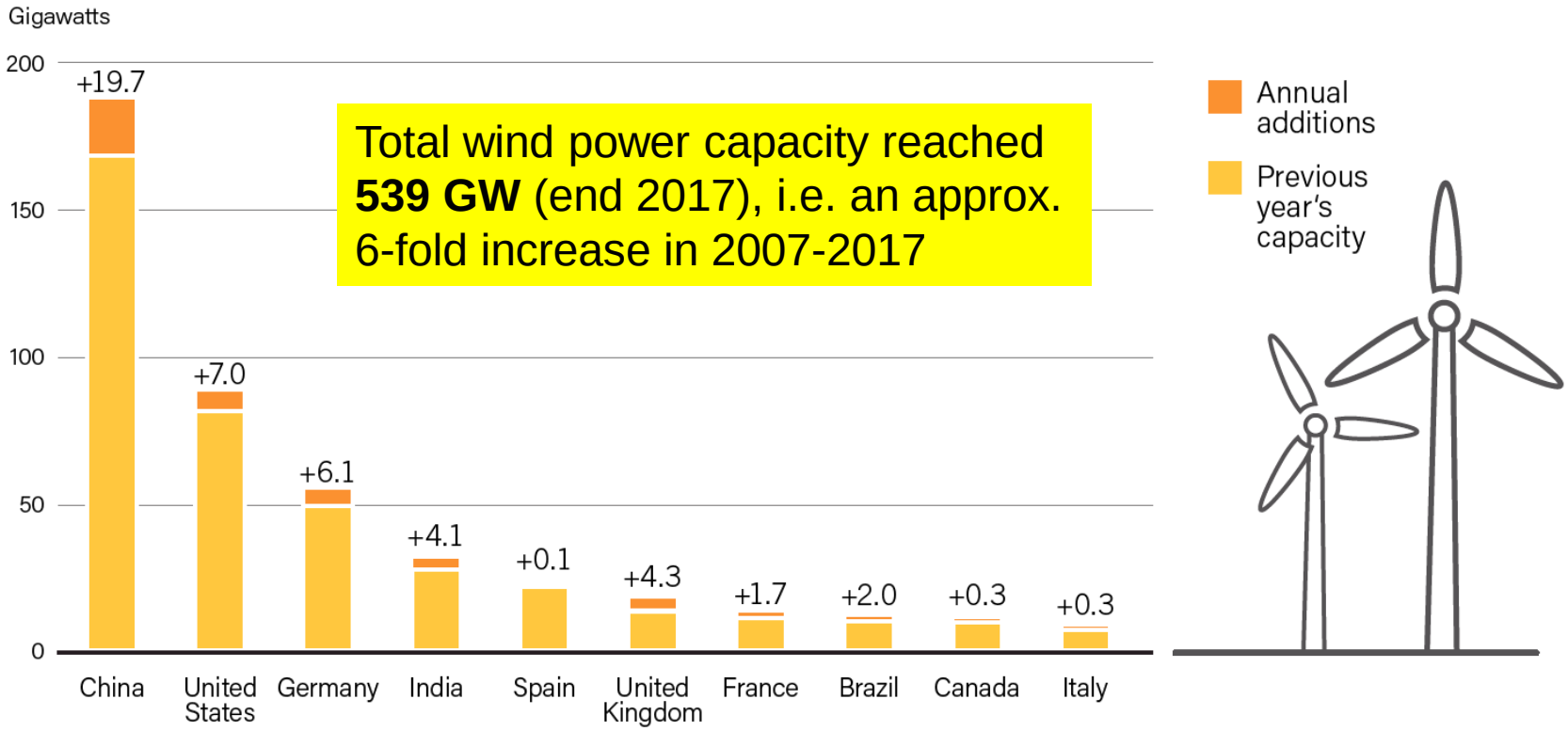
Jeff Tollefson, 2018. "Clock ticking on climate action" NATURE, Vol.562, 11-OCT-2018, p. 172-3



- Global shares and recent developments

Global shares and recent developments

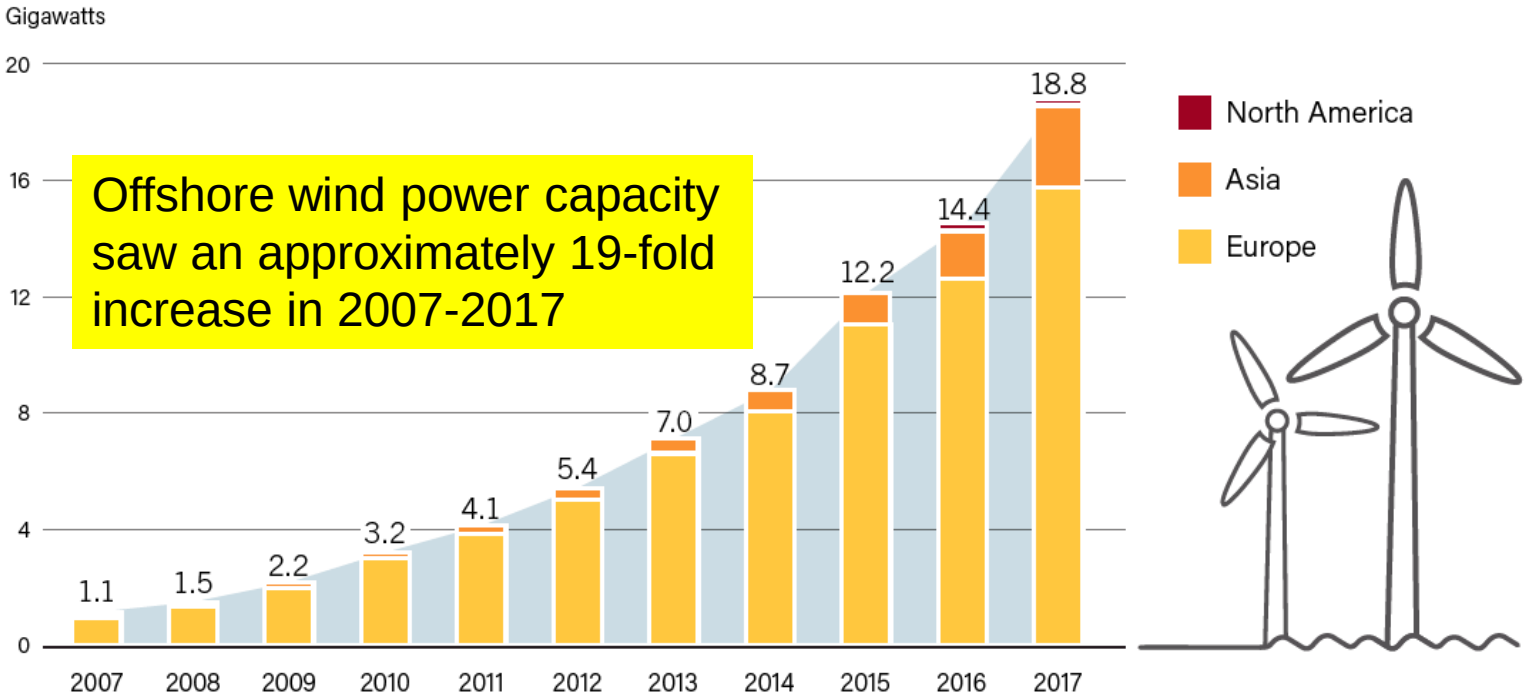
- Wind power capacity and additions (2017), Top 10 countries in 2017



- Onshore wind power continues to account for 96% of global installed capacity
- Nine countries connected a total 4.3 GW of offshore wind capacity during 2017 alone, increasing total world offshore capacity up to 18.8 GW. REN21

Global shares and recent developments

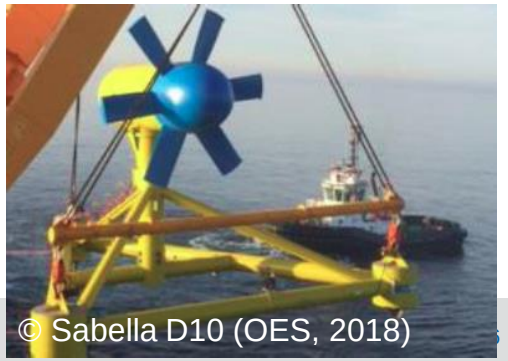
- Wind power offshore capacity by region in 2007-2017

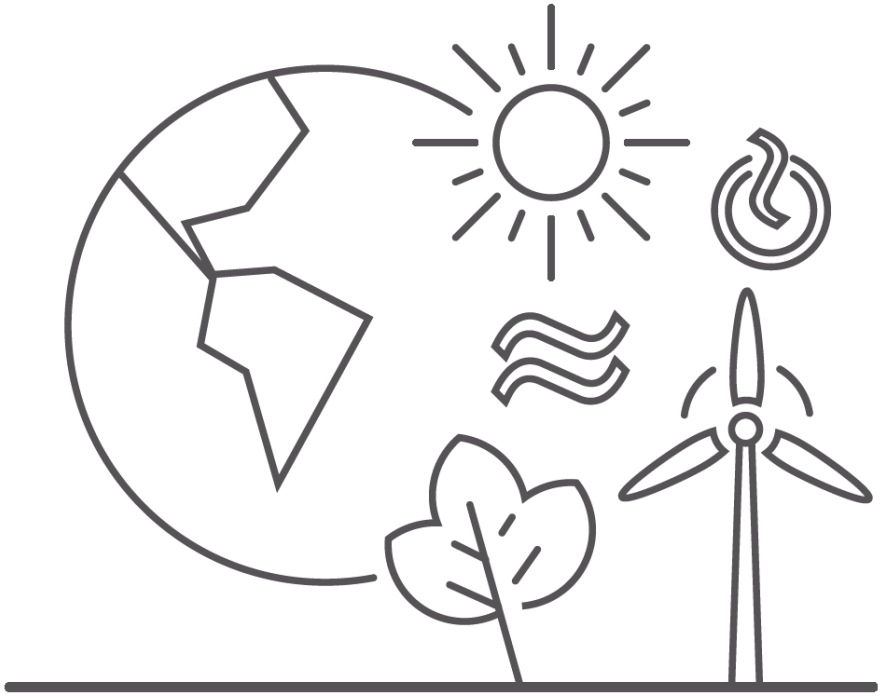


- Top countries for offshore additions were the UK (1.7 GW), Germany (1.2 GW) and China (1.2 GW) ► Europe 15.8 GW
- China's offshore market took off in 2017 with 2.8 GW, and a further 5 GW under construction.
- Vast offshore capacities in Taiwan with set target of 5.5 GW until 2025!

Global shares and recent developments

- Ocean energy remains a largely untapped renewable energy source, despite decades of development efforts.
- Only 529 MW (i.e. 1/40 of Offshore Wind) of operating capacity worldwide, of which >90% is represented by only two major tidal barrage facilities (REN21, 2018)
  - Large tidal range facilities, e.g. *Sihwa* (254MW) and *La Rance* (240MW), use mature and well-established in-stream turbine technologies.
  - UK proposed new Swansea Tidal Lagoon project with installed capacity of 320 MW
- Yet, open-water technologies, such as tidal stream and wave energy converters, are generally in an earlier stage of development with various prototypes deployed/piloted

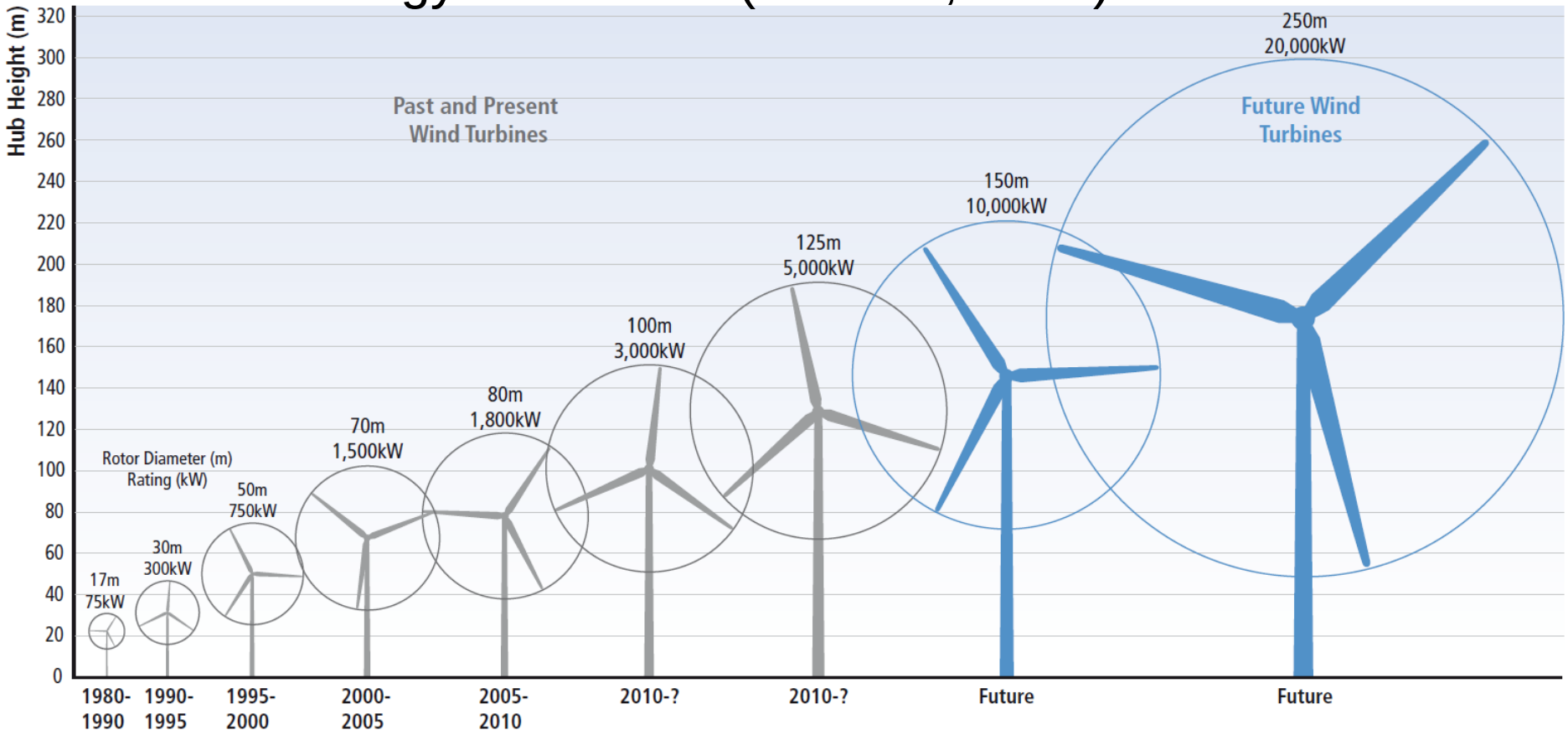




- Guiding principles
  - ► Innovations and trends

Guiding principles ► Innovation and trends

- "Size matters" to cut LCOE ►Evolution of offshore wind energy converters (SRREN, 2012)



SRREN from IPCC, 2012

Guiding principles ► Innovation and trends

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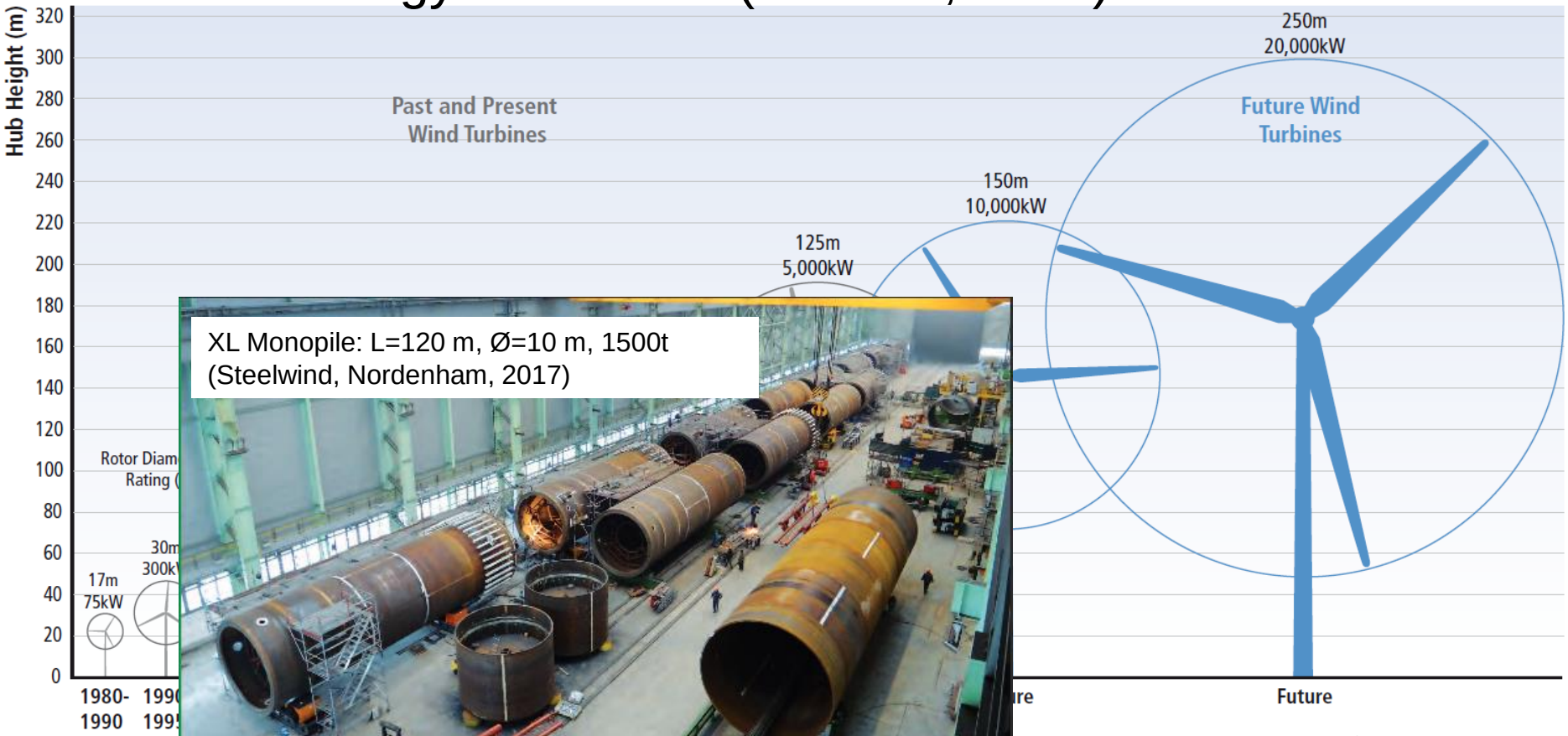
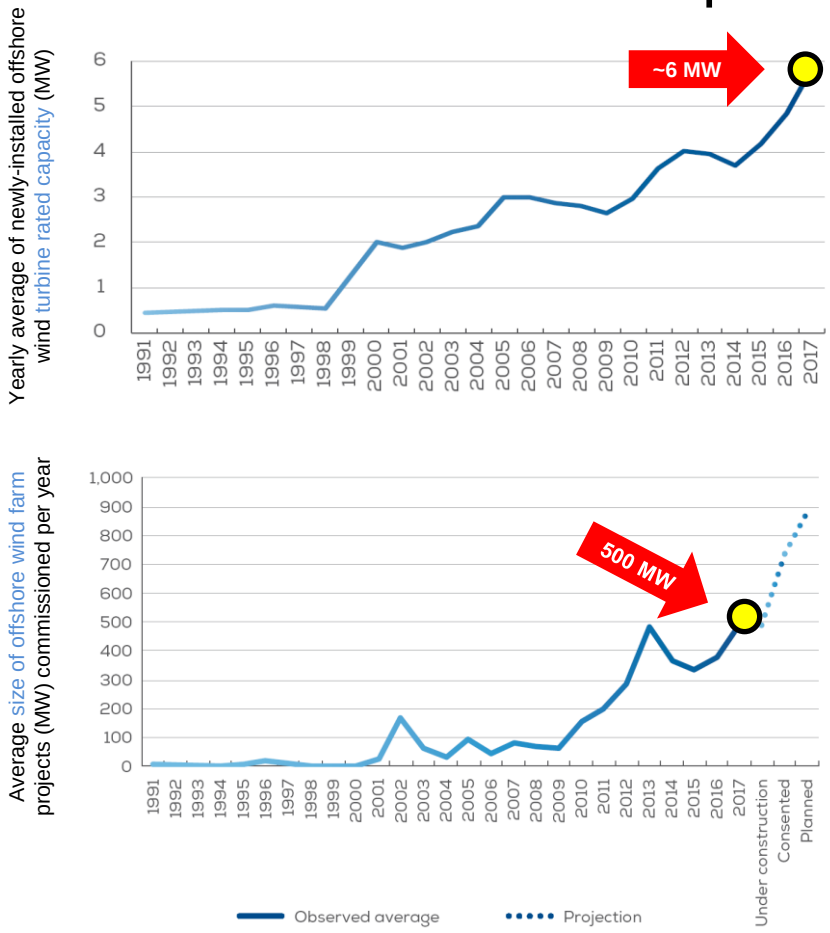
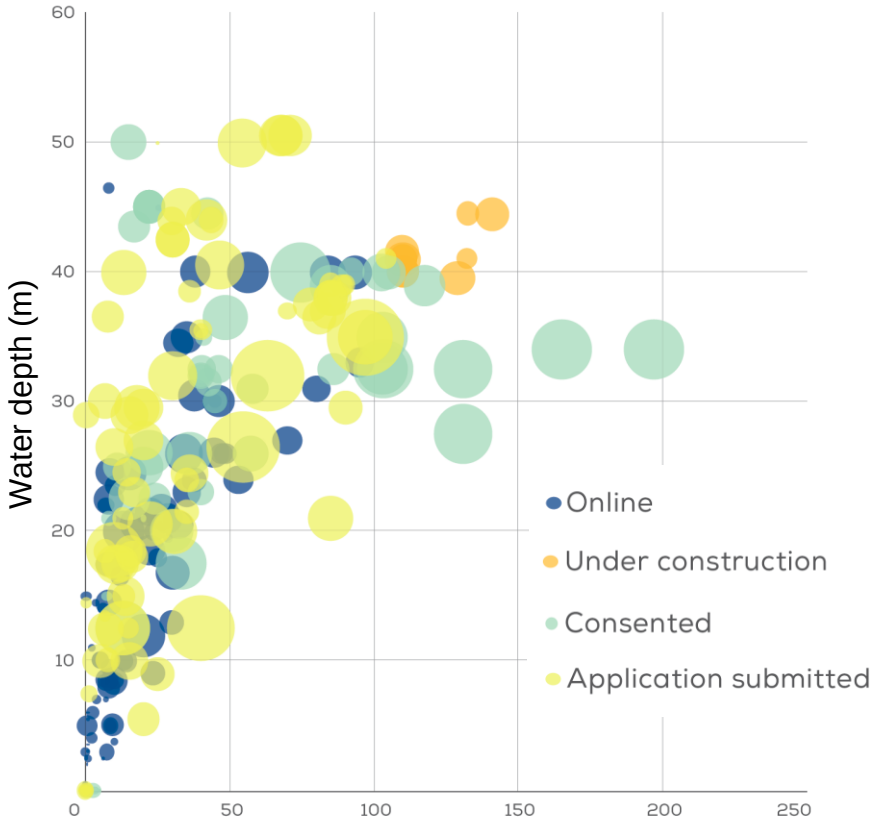


SRREN from IPCC, 2012

Guiding principles ► Innovation and trends

- Turbine size, windpark size, water depth and distance from shore in European water (Wind Europe, 2018)

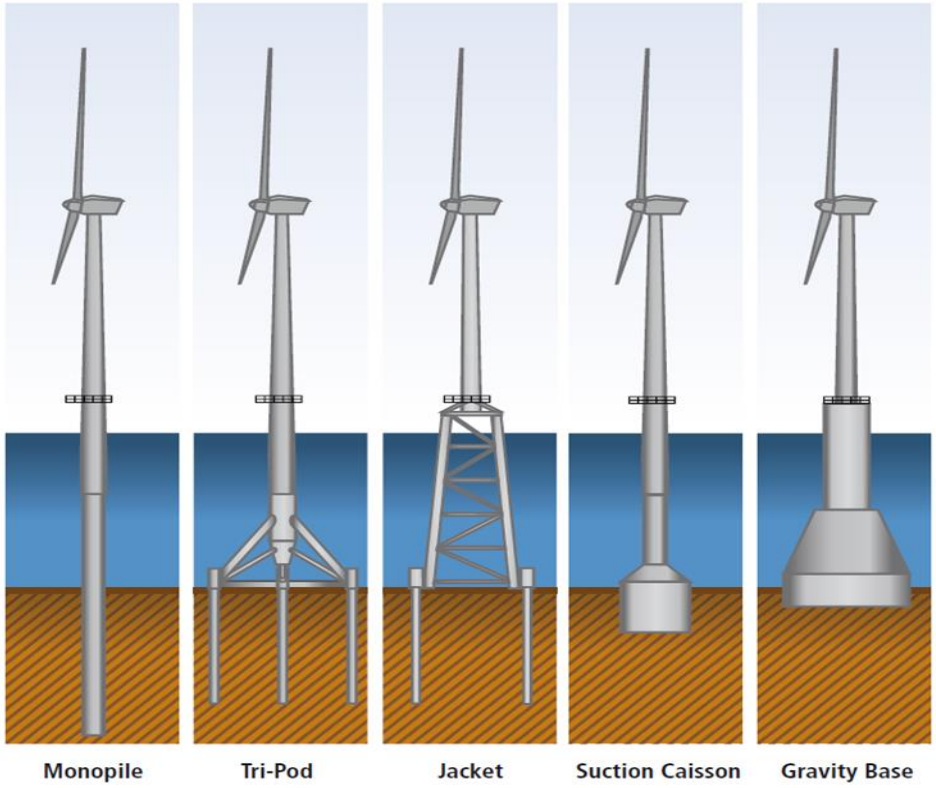




Wind Europe, 2018

Guiding principles ► Innovation and trends

- Types and share of substructures for bottom-fixed offshore (BFOW) wind turbines in Europe (Wind Europe, 2018)



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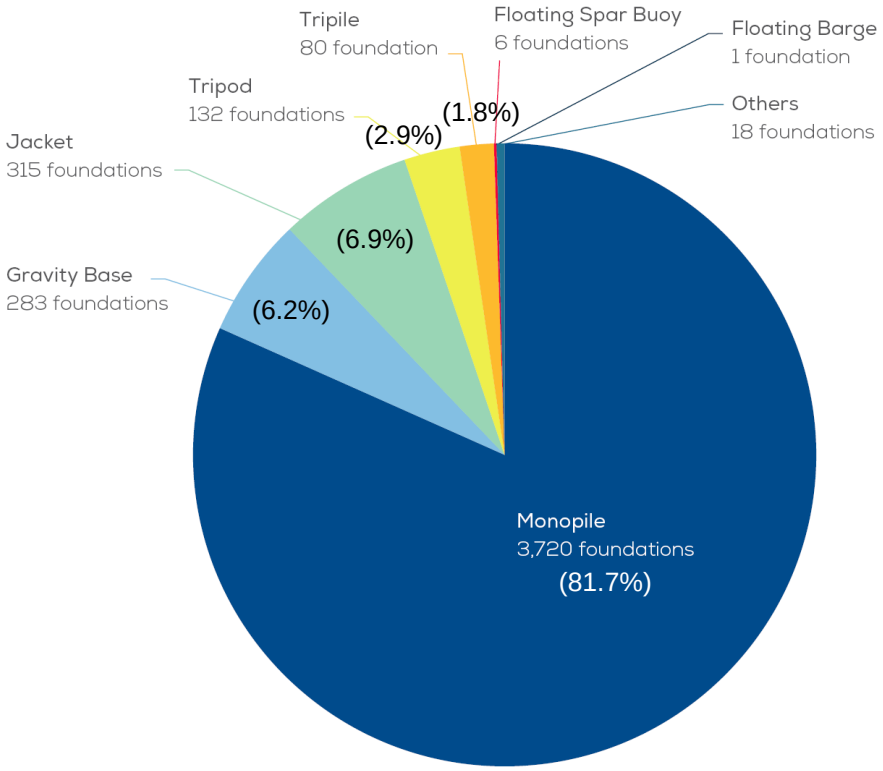
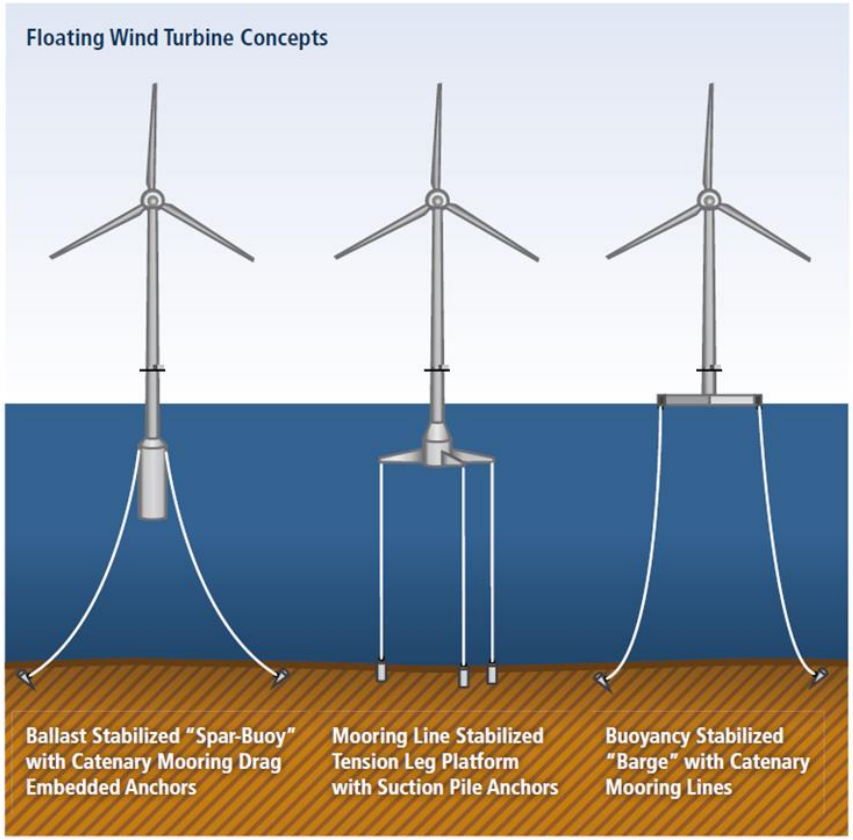


Wind Europe, 2018

Guiding principles ► Innovation and trends

- The “new kid” in European waters (Wind Europe, 2018)



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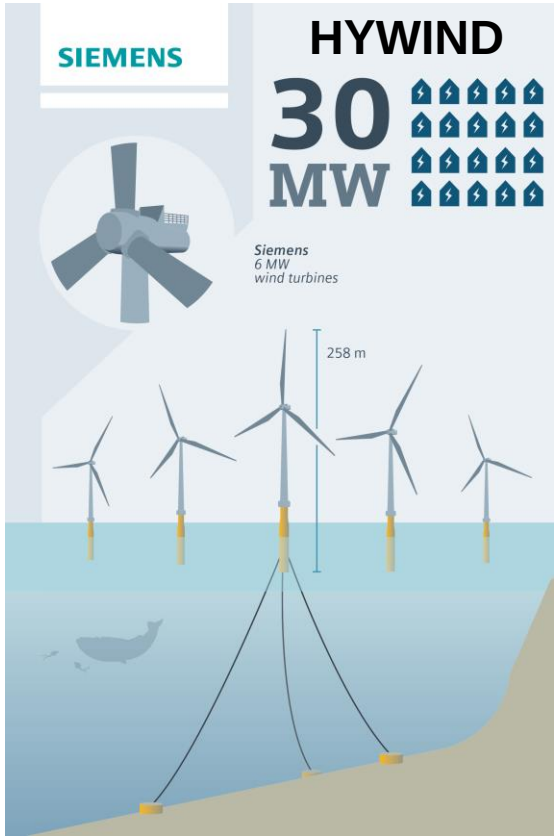


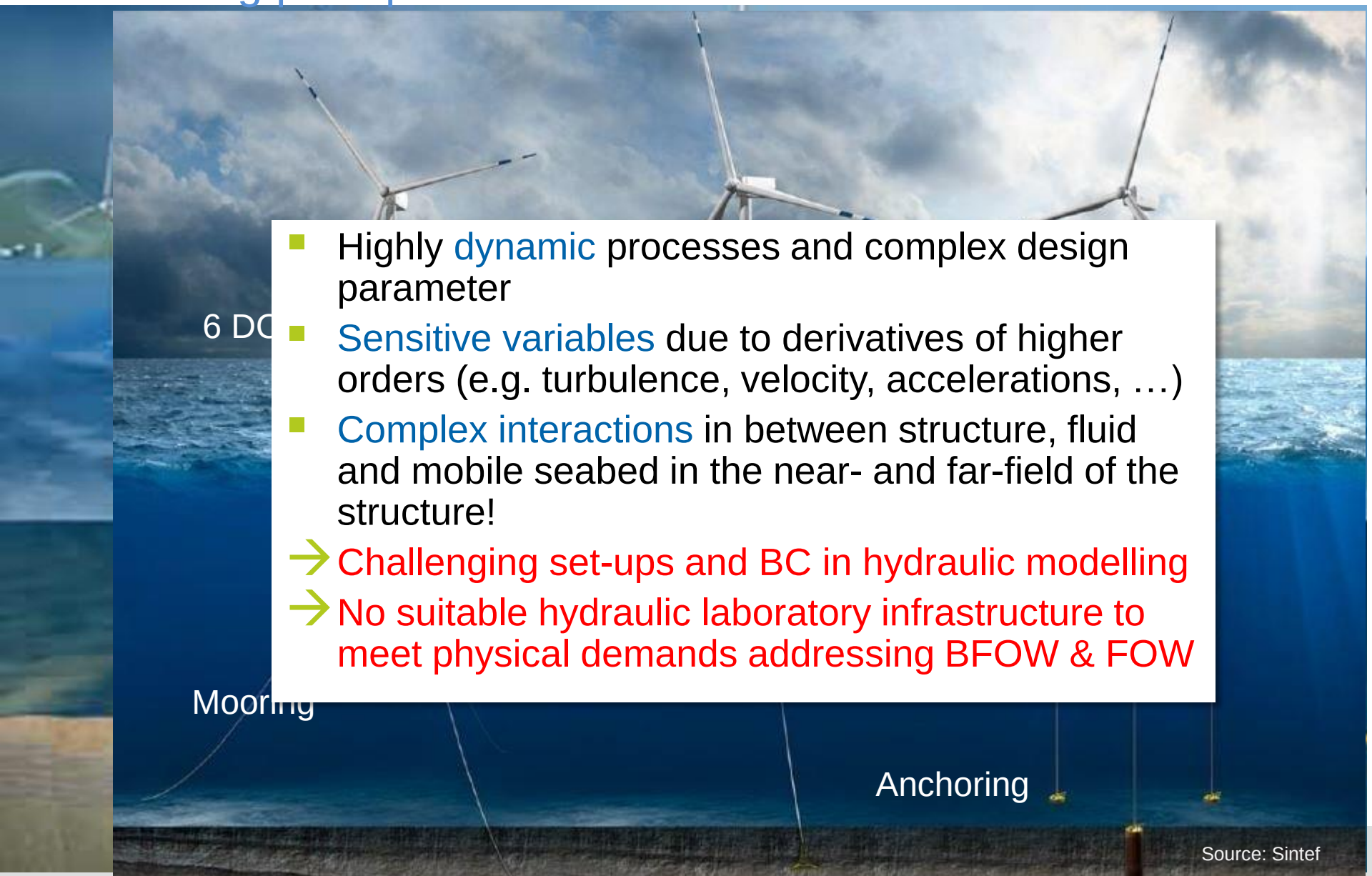
© SIEMENS, 2018

First large-scale FOW wind park HYWIND carried out by Equinor

Installed by end of 2017 with Siemens turbines:

- 5x6 MW turbines
- 135 GWh/a yield
- Water depth 90-120 m
- Distance shore: 25 km

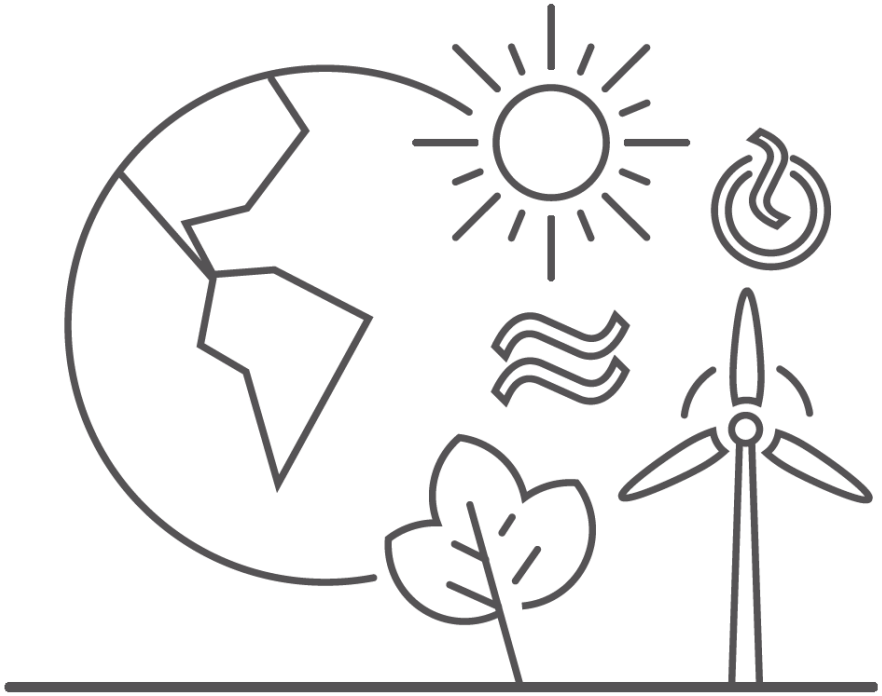
Guiding principles ► Innovation and trends



- Highly dynamic processes and complex design parameter
- Sensitive variables due to derivatives of higher orders (e.g. turbulence, velocity, accelerations, …)
- Complex interactions in between structure, fluid and mobile seabed in the near- and far-field of the structure!

→ Challenging set-ups and BC in hydraulic modelling

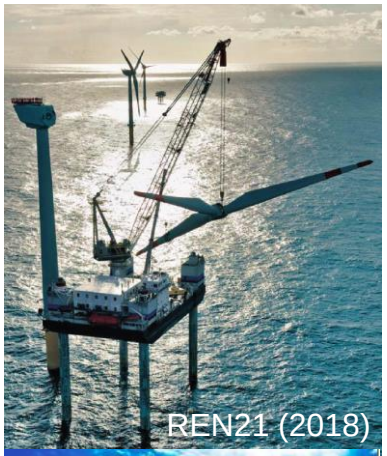
→ No suitable hydraulic laboratory infrastructure to meet physical demands addressing BFOW & FOW



- Reverse side of the coin
  - ► Challenges

Reverse side of the coin ► Challenge #1

- Offshore wind and marine renewable energy industry is increasingly mature and delivers commercially proven solutions with ever decreasing LCOE
- Yet, marine RE technologies likely impose and are proven to cause detrimental effects in marine environment (high confidence!)
- Profound lack of robust assessments on environmental effects (data and studies) reveals demand for progressed real-world studies and monitoring programmes, e.g.
  - Structural-induced changes in physical system (e.g. flow field, geomorphology, sediment fate)
  - Changes on marine habitats
  - Underwater noise during installation/operation

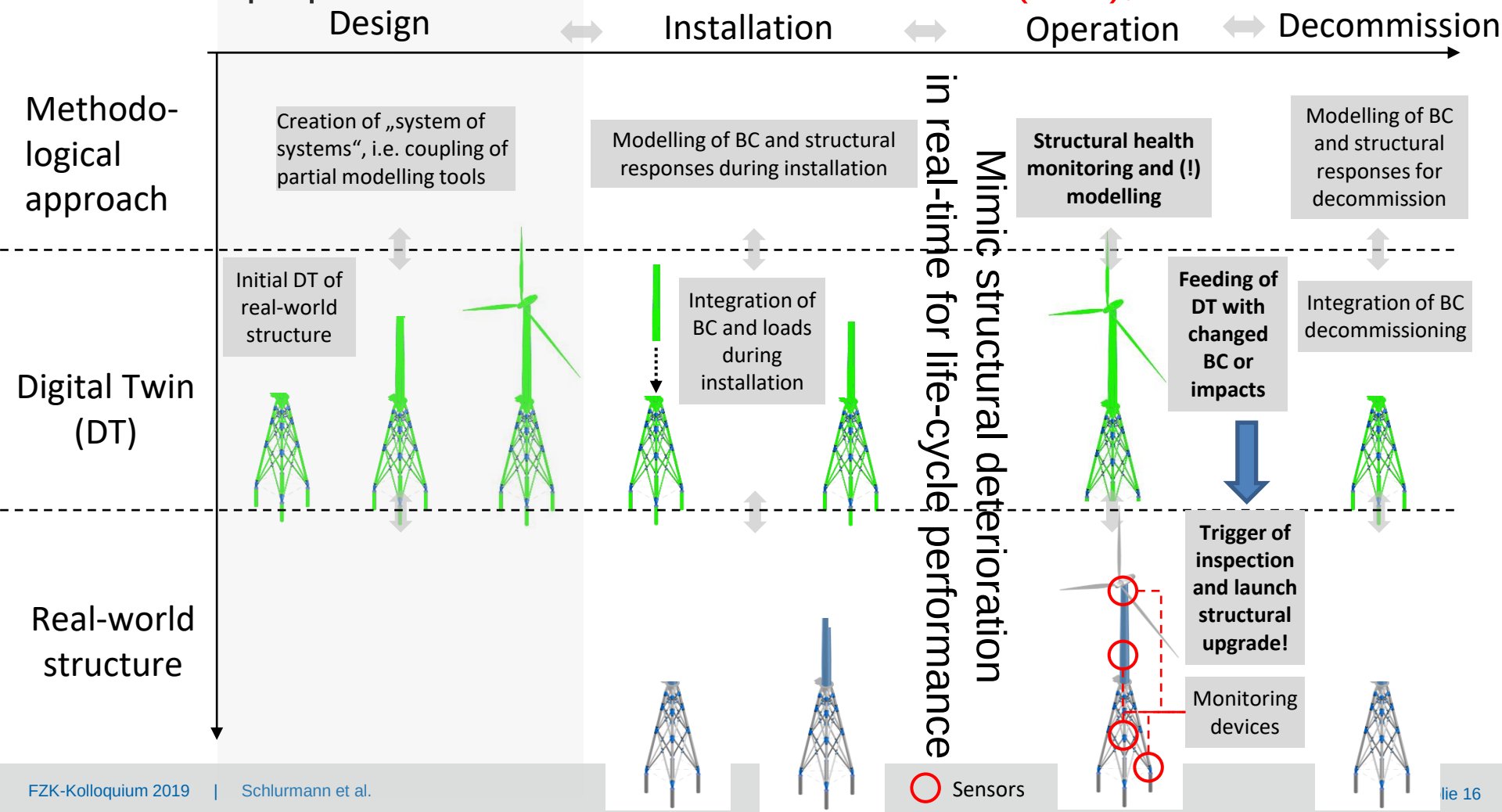

REN21 (2018)

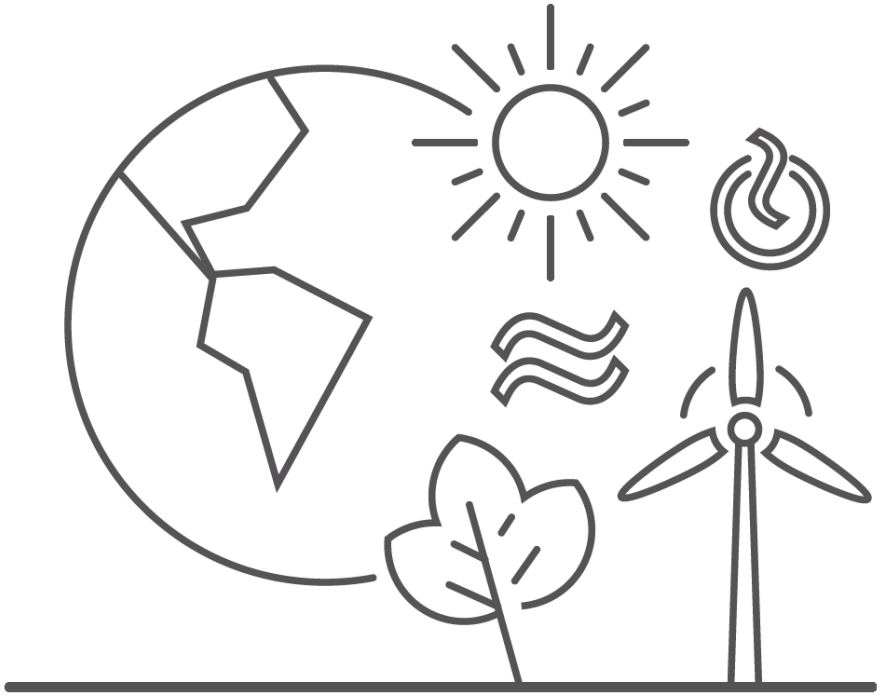

Copping et al. (2016)


Copping et al. (2016)

Reverse side of the coin ► Challenge #2

- Key knowledge gap: **Installation vs. operation** (life-cycle)
  - proposed Collaborative Research Centre (SFB), Univ. Hannover





- BMWi funding schemes
  - ► marTech realization

Bundesministerium für Wirtschaft und Energie

Niedersächsisches Ministerium für Wissenschaft und Kultur

Leibniz Universität Hannover

Technische Universität Braunschweig

13.10.2017 **GEMEINSAME PRESSEMITTEILUNG** Erneuerbare Energien

Projekt ‚marTech': Rund 35 Millionen Euro für die Erweiterung des Großen Wellenkanals in Hannover

Bundesministerium für Wirtschaft und Energie fördert den deutschlandweit größten Versuchsstand für die kombinierte Untersuchung von Belastungen durch Seegang und Strömung.

BMWi funding schemes ► marTech

Bundesministerium für Wirtschaft und Energie

- Research project marTech - R&D of Maritime Technologies for Reliable and Sustainable Energy Supplies
  - Contributions to advance understanding on maritime technologies under consideration of wave-current-structure-seafloor-interactions in an upgraded GWK*plus*
  - Three embedded pilot research projects which scrutinize real-world environmental conditions (no idealizations, i.e. simulation of tidal current)
  - Strong collaboration with industry partners

    NAUE www.naue.com
    mibau MINERALIEN FÜR DIE BAUINDUSTRIE
  - Support from renowned industry partners (LOI)

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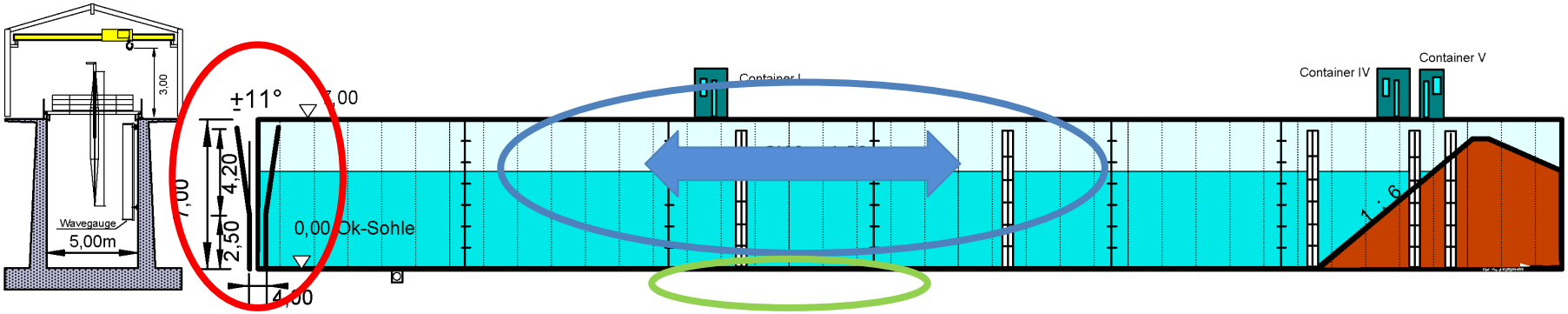
BASF We create chemistry
Boskalis
BERDING BETON
VOITH HYDRO POWER GENERATION
RAMBØLL
SINNPOWER
wpd think energy
ONP Management
GMT
maritimes cluster norddeutschland

BMWi funding schemes ► marTech realization

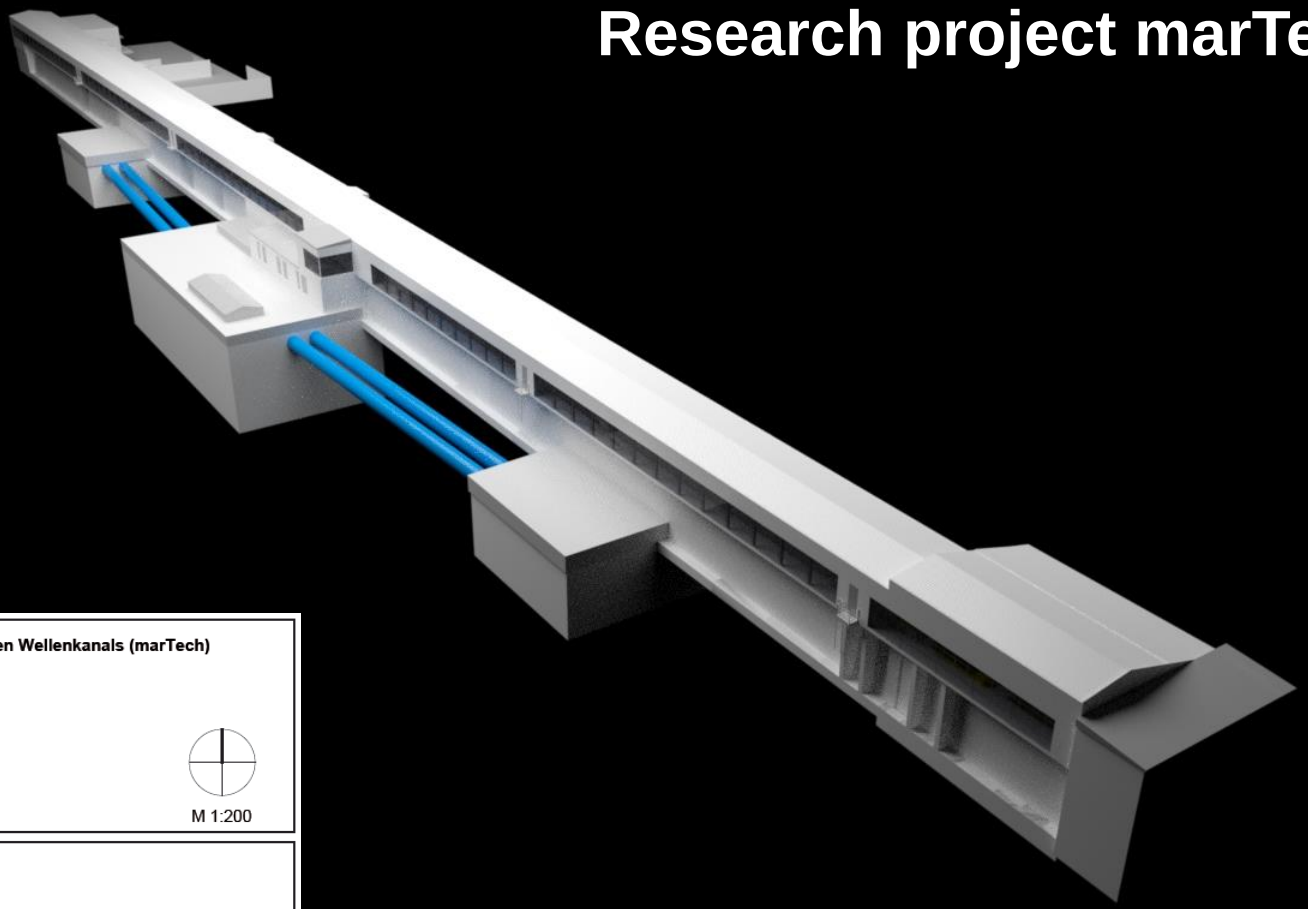
- marTech phases 1, 2a & 2b

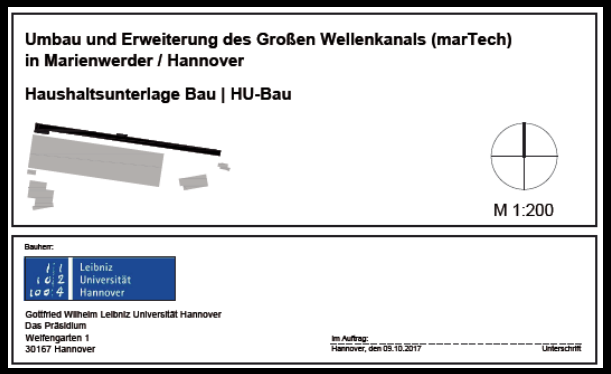


- Substitution of wave maker: Generation of larger waves and impacts, prototype scaling, development and exploitation of maritime structures under extreme conditions due to altered environmental drivers
- New (tidal) current generation facility: Generation and analysis of impacts stemming from tidal currents on infrastructure and seafloor in context of nonlinear wave-current interaction with additional adjustment of tidal water level
- New shallow and deep sandpit: Uniform deployment of sediment: Shallow sandpit (-2m), and in addition deep sandpit (-6m) meant for real-world geotechnical embeddedness of maritime structures, Analysis of nonlinear structure-seafloor-interaction to advance knowledge on embeddedness, bed degradation and life-time assessment

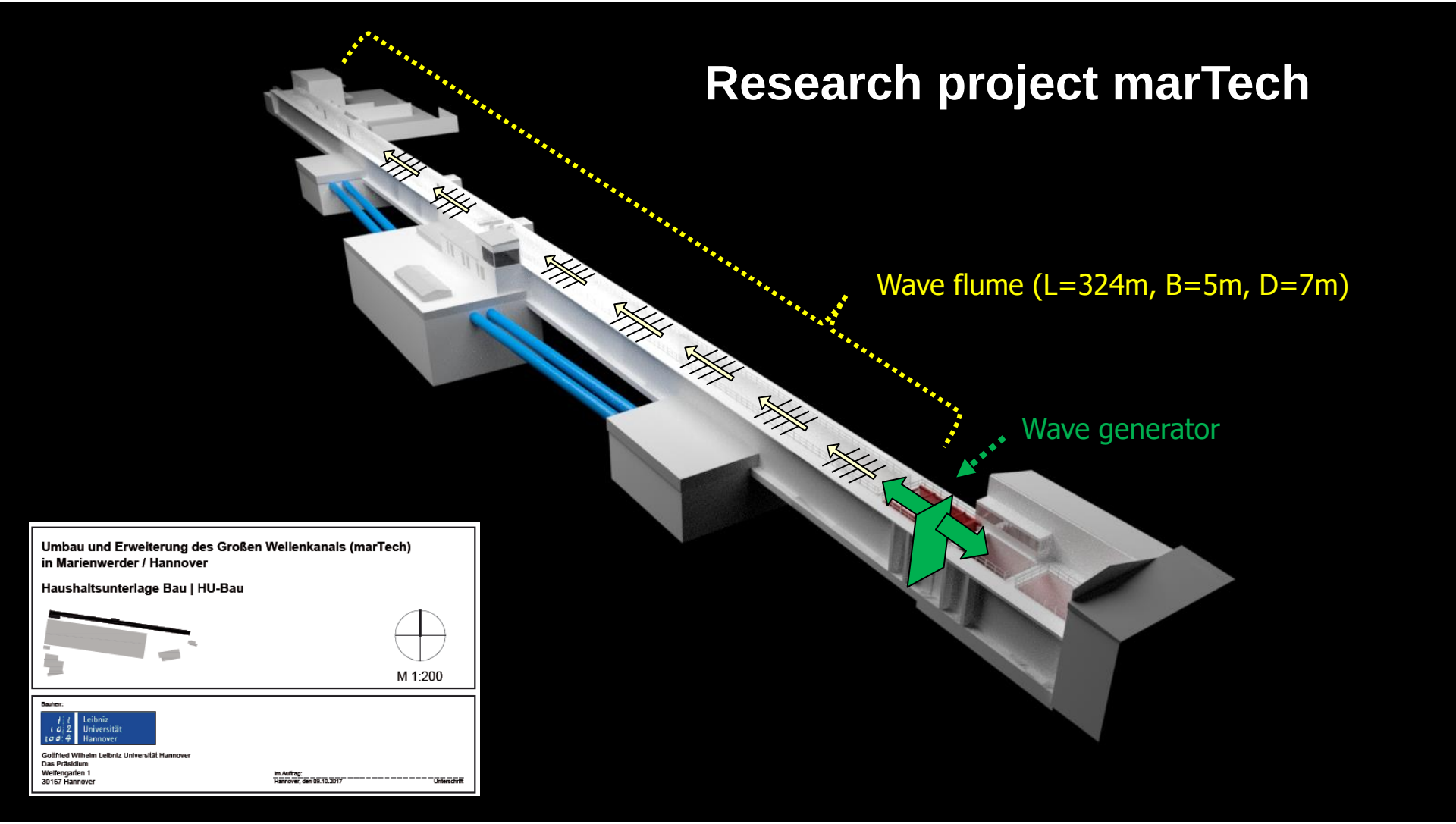
BMWi funding schemes ► marTech realization

Research project marTech





BMWi funding schemes ► marTech realization



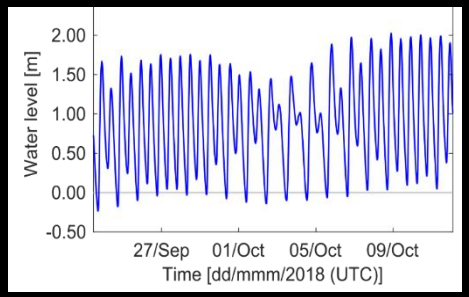
BMWi funding schemes ► marTech realization

Research project marTech

Current outlet

Q = 12.500 l/s

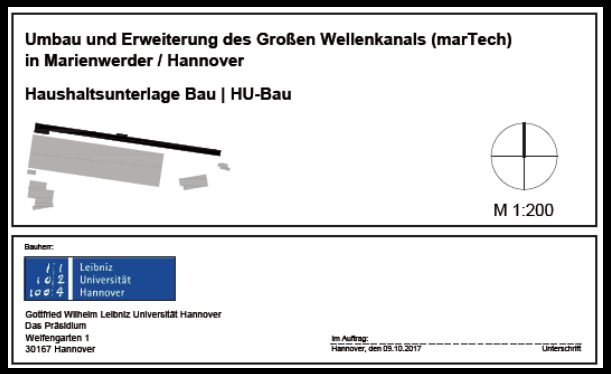
Current generation (Power-pumps) to allow for tidal currents (reversal of flow)



Adjustment of water level to mimic tidal conditions

Wave generator

Current inlet



BMWi funding schemes ► marTech

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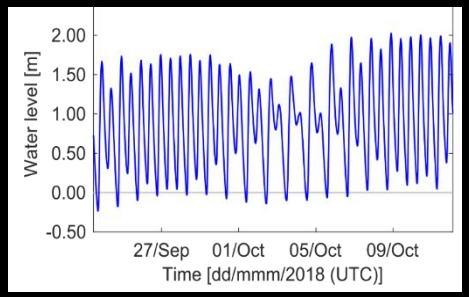

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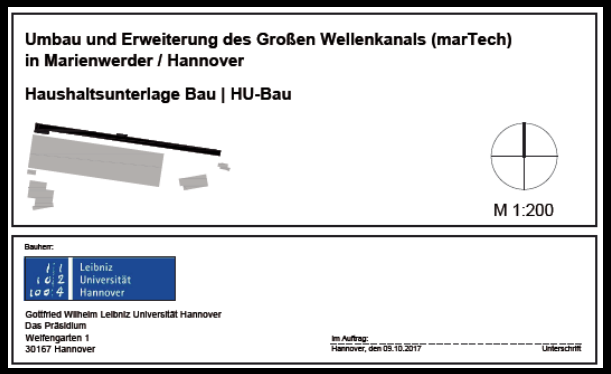
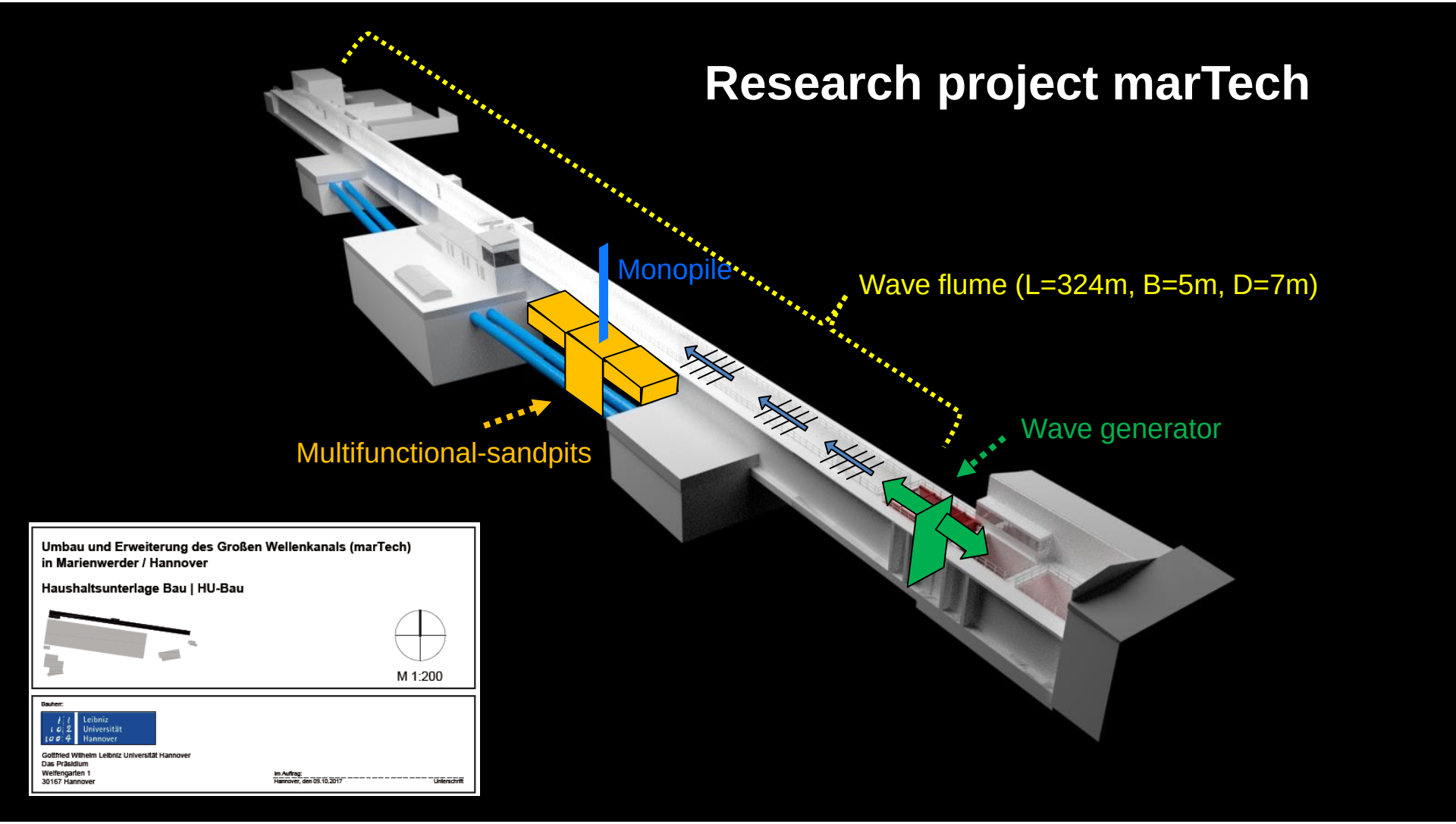
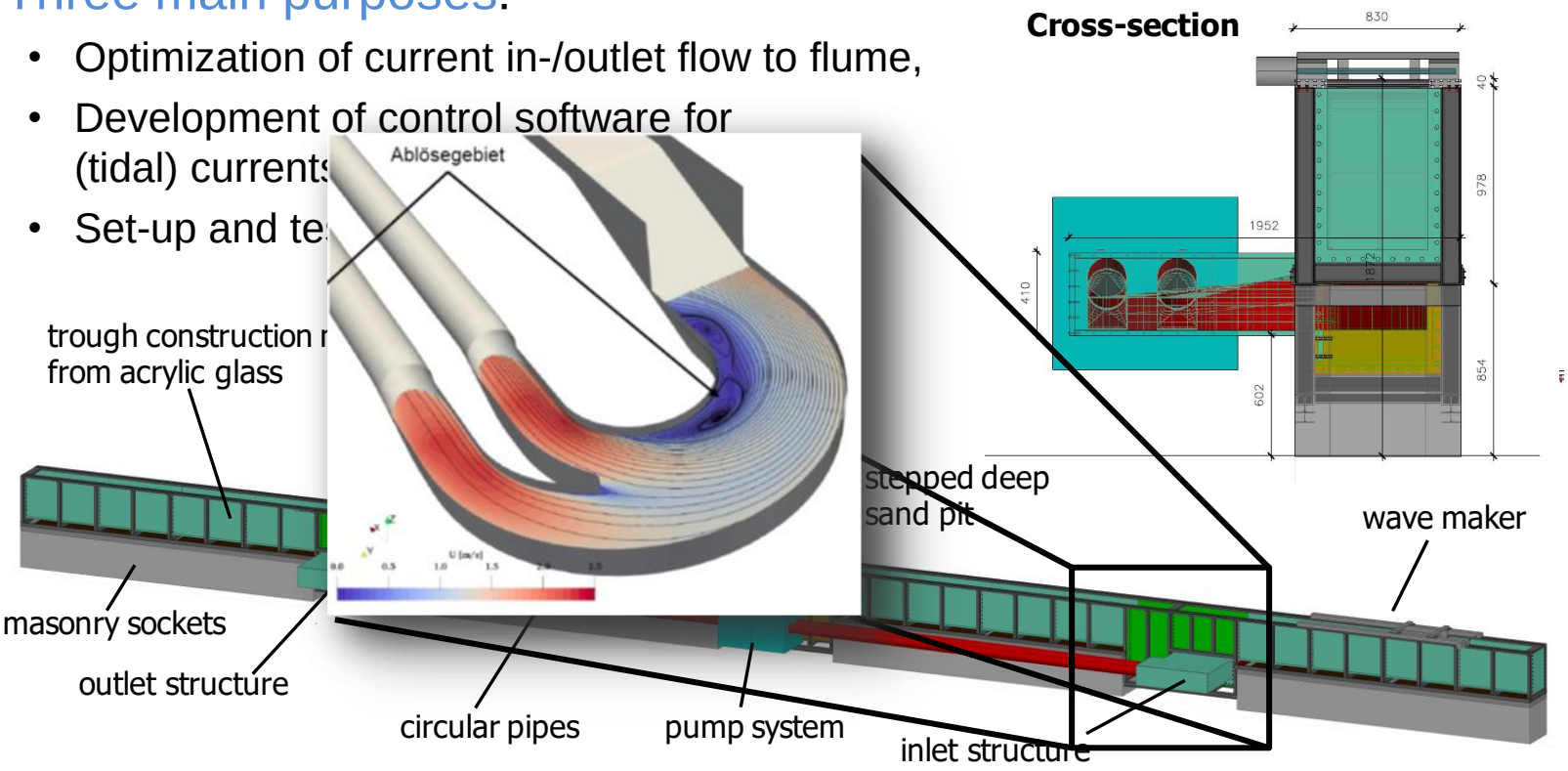


BMWi funding schemes ► marTech realization



BMWi funding schemes ► marTech realization

- Design of 1:10 model of GWK*plus*
  - New physical model of upgraded GWK in physical scale of 1:10 (length 30m, width 0,50m, height 0,80m)
  - Three main purposes:
    - Optimization of current in-/outlet flow to flume,
    - Development of control software for (tidal) currents
    - Set-up and te



BMWi funding schemes ► marTech realization

- Design of 1:10 model of GWK*plus*


Thruster boxes


Inlet geometry made by milling from a massive block of polyurethante foam


Rim-driven thruster for current generation


Inlet geometry with extended guiding wall

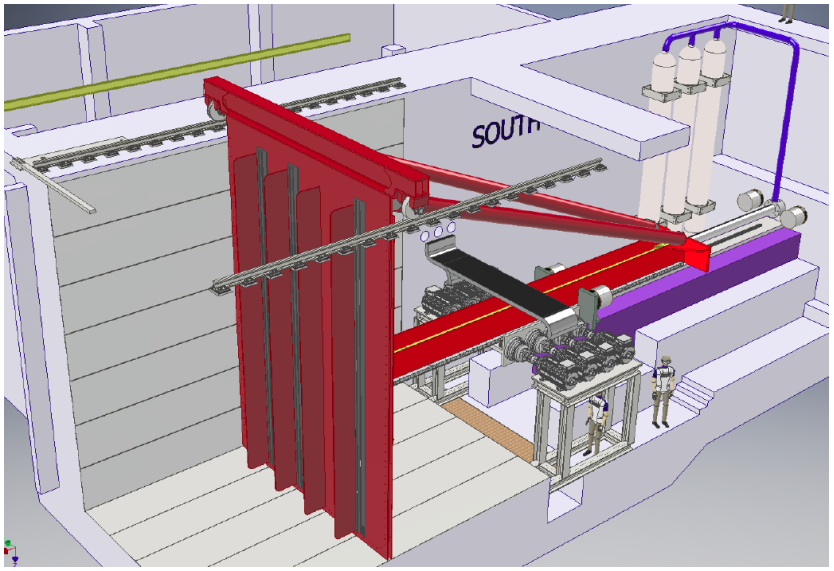
Steel frame and acrylic glass section for current inlet with rectangular opening for the inlet box with the inlet geometry and guiding wall, (Bruehl et al., 2018)

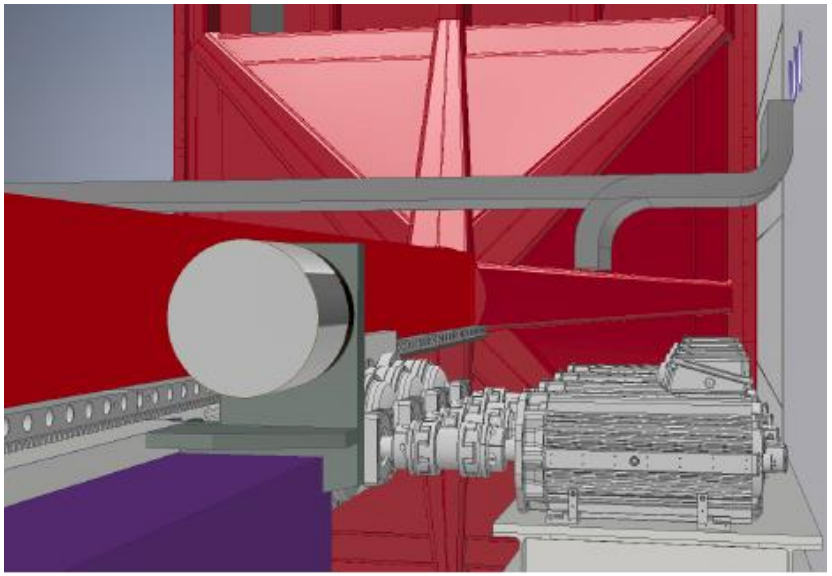
BMWi funding schemes ► marTech realization

- Formal inauguration miniGWK*plus* Feb. 19th, 2019

BMWi funding schemes ► marTech realization

- Developing a ***tailor-made*** new wavemaker (BRNL) with consultants (GRBV et al.) meeting user demands (FZK)



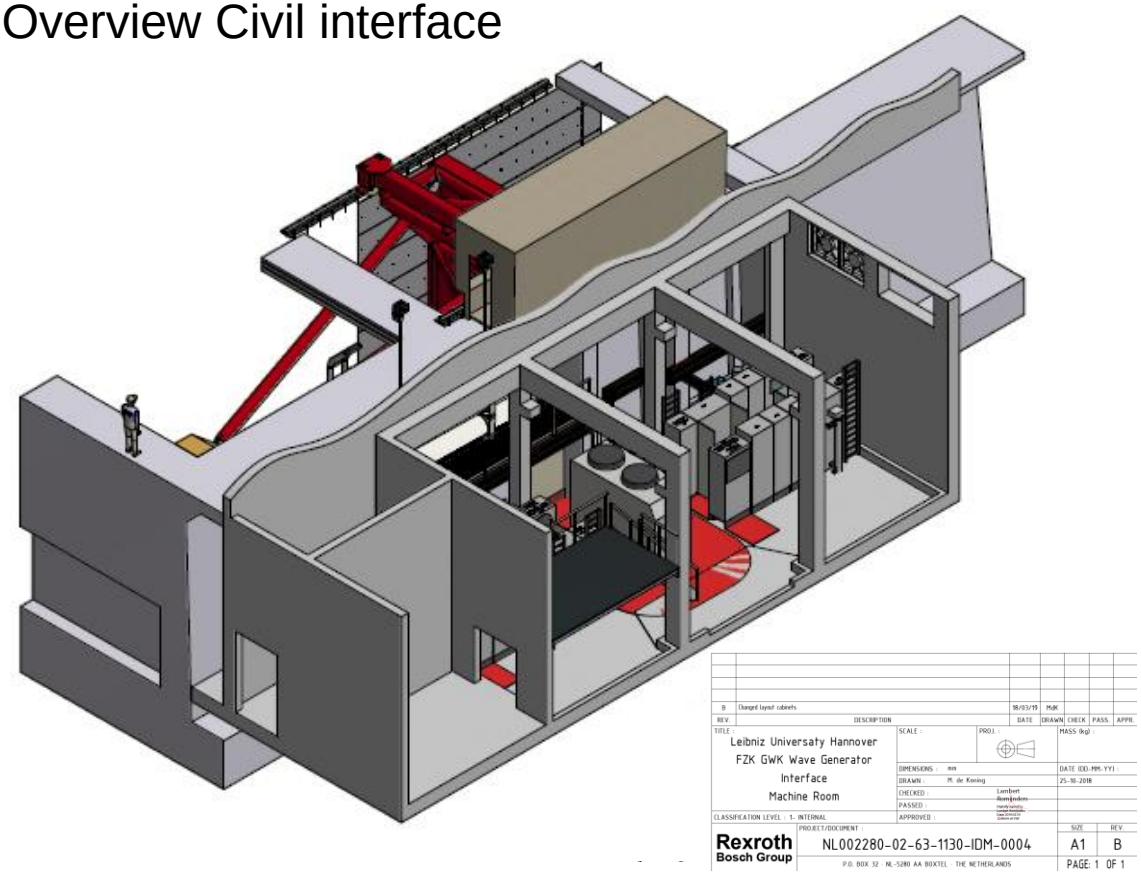


- Bosch-Rexroth wave generator with dry-back piston-type wave board
- 2x4 electro-mechanical system with AC servo motors, i.e. rack&pinion enabling high speeds and large displacements (S >7,8m, vel >2,8m/s)
- Pneumatic system designed to counter the hydrostatic force on the wave board

BMWi funding schemes ► marTech realization

- Developing a ***tailor-made*** new wavemaker (BRNL) with consultants (GRBV et al.) meeting user demands (FZK)

Overview Civil interface



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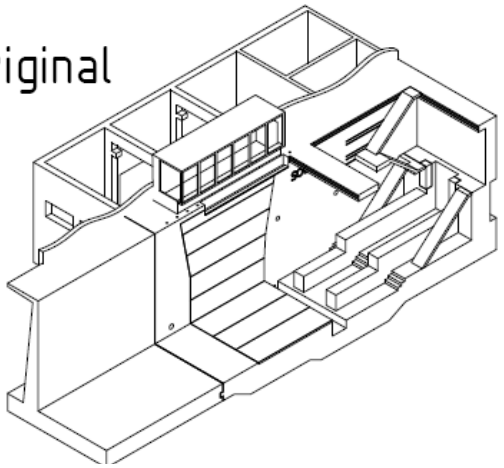
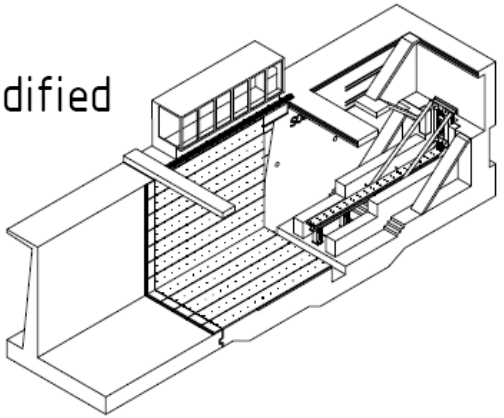


Modified



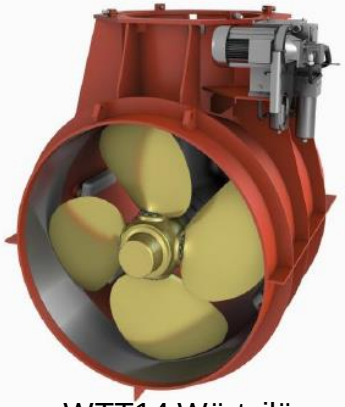
BMWi funding schemes ► marTech realization

- Developing a ***unique*** current generation system with consultants (GRBV et al.) meeting user demands (FZK)

Ground plan

Current outlet

2x thrusters



e.g. WTT14 Wärtsilä

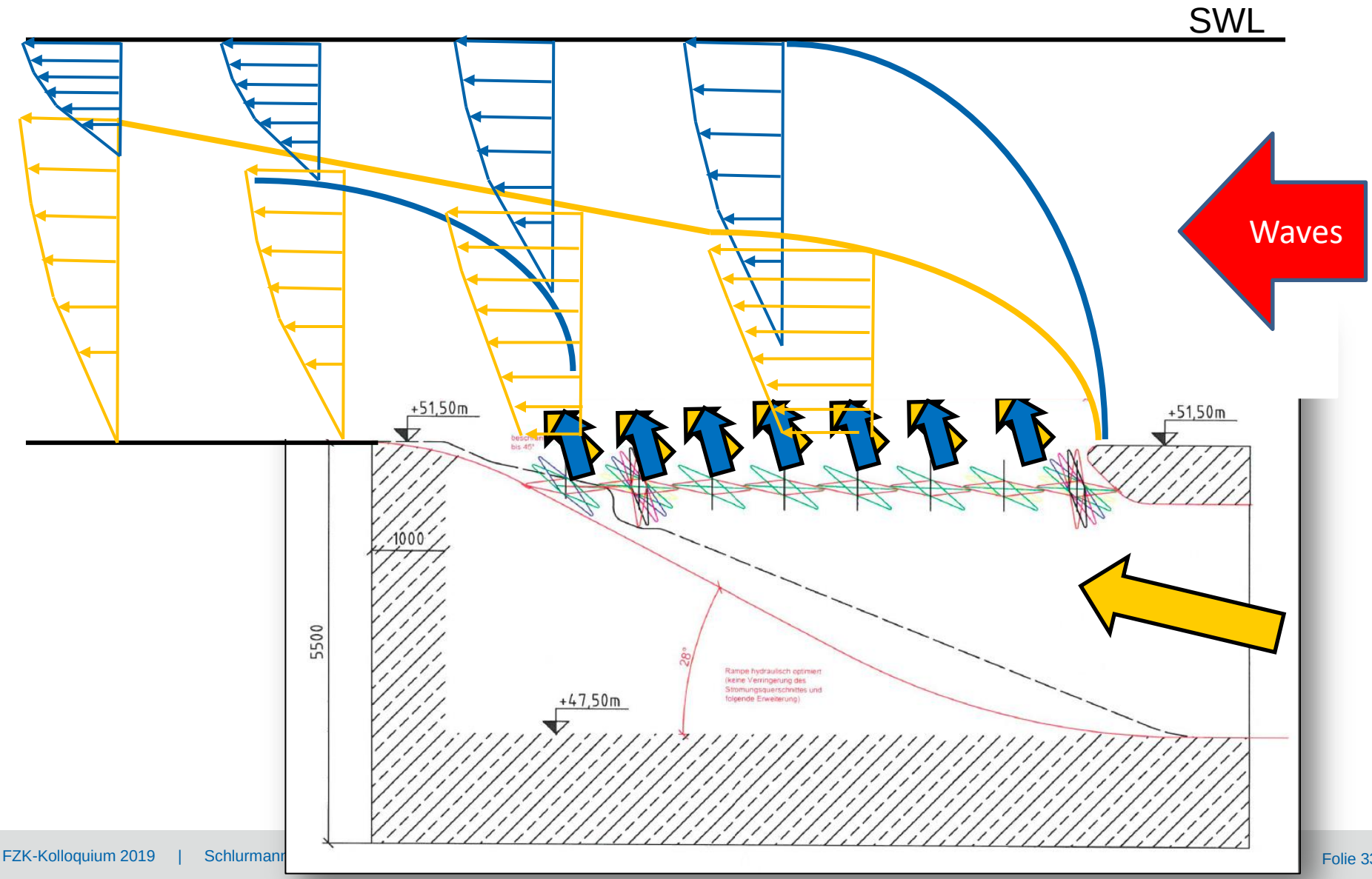
Current generation (Power-pumps)

Current inlet

Longitudinal view

Bow thrusters cruise vessels

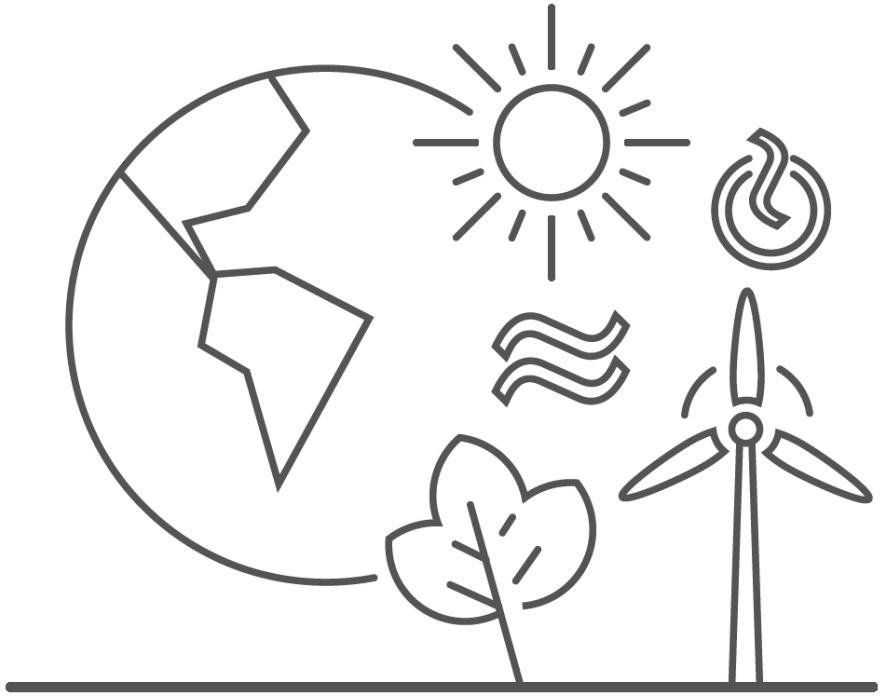
BMWi funding schemes ► marTech realization



BMWi funding schemes ► marTech realization

- Timeline, *our* lessons learned (so far)!
  - Planning! Final design of GWK*plus* is about to be finished. Preparatory work (deforestation, construction road, logistics) began in Q1 until Q3/2019!
  - Schedule! Construction works are projected to commence Q4/2019! >6-8 months delay!
  - Schedule! Downtime GWK 24 months, i.e. terminate construction works in Q4/2021!
  - Thorough planning, preparations and communication! …are key!


View North of GWK, Mar 2019



- Summary ▶ Key messages

Summary ► Key messages

- Globally installed offshore wind capacities 18,8 GW (2017) with innovators in Europe and China
  - Total wind power capacity (on- and offshore) saw an approximately 6-fold increase in 2007-2017
  - Offshore wind power capacity saw an approximately 19-fold increase in 2007-2017
    ► capacities >500GW by 2050
- Developments show larger turbines/farms and distances/depths
  - Progress research concepts from BFOW to FOW
- Research on environmental effects and simulation of deteriorating offshore wind farms over life-cycle demanded!

GWK*plus* marTech contributes aspects in research esign!

…but there's still a long way to go!

marTech[#] - Development of Maritime Technologies for Reliable and Sustainable Renewable Energy Supply

Thanks for your kind attention!

T. Schlurmann[1,3], M. Brühl[2], N. Goseberg[2,3], A. Schendel[1] and S. Schimmels[3]

[#]marTech is granted with the support of the Fed. Min. for Economic Affairs and Energy (BMWi) with funding number 0324196A-B, 2017-21

Federal Ministry for Economic Affairs and Energy

BMWi funding schemes ► marTech

- GWK in relation to other laboratory facilities

	Institution	In operation since	Length Width Height	max wave height H_{max}	current Q_{max}	Sand pit(s)
Old Delta Flume	Deltares (Netherlands)	1979	240 m 5,0 m 7,0 m	2,5 m	-	2,0 m
GWK	FZK (Germany)	1983	309 m 5,0 m 7,0 m	2,1 m	-	-
CIEM	UPC (Spain)	1994	100 m 3,0 m 4,5 m	1,6 m	2 m³/s	-
Large Hydro- Geo Flume	PARI (Japan)	2000	185 m 3,5 m 8,0 m	3,5 m	20 m³/s	4,0 m
Quebec Long Flume	INRS-ETE (Canada)	2011	120 m 5,0 m 5,0 m	1,8 m	5 m³/s	-
New Delta Flume	Deltares (Netherlands)	2014	300 m 5,0 m 9,5 m	3,5 m	-	-
Large Wave Flume (LWF)	TIWTE (China)	2015	450 m 5,0 m 8,0 m	3,5 m	20 m³/s	4,0 m
GWK*plus*	FZK (Germany)	(2021)	309 m 5,0 m 7,0 m	2,7 – 3,0 m	12,5 m³/s	2,0 m und 6,0 m