How do Estonian companies participate in international offshore wind energy industry?
SIWT - the Sea Ice Wind Turbine – demonstration from Estonian Wind Power Cluster

The Estonian Offshore Wind Energy Conference

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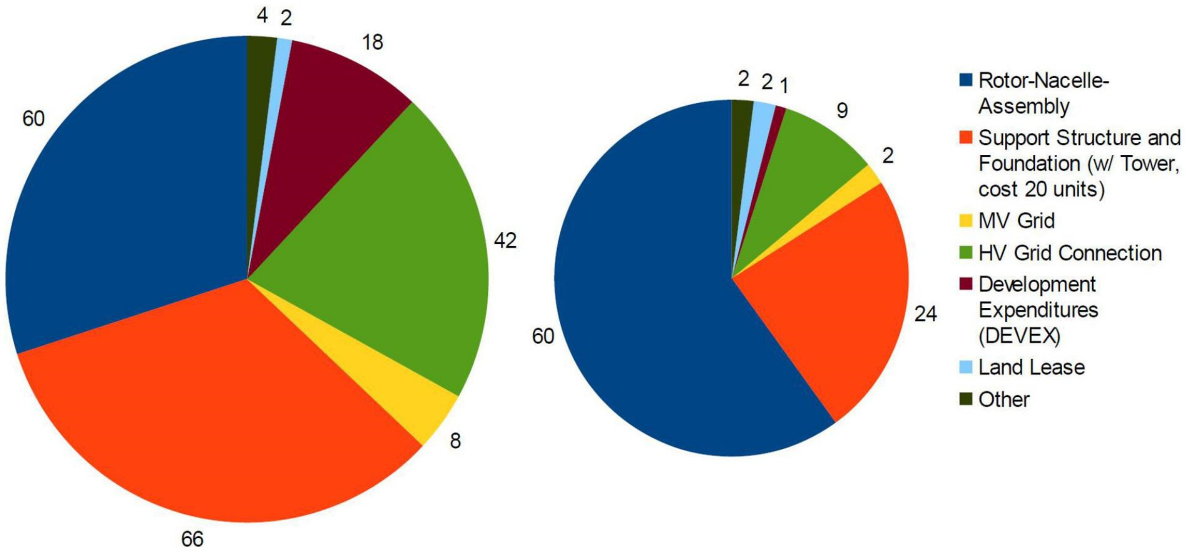
Offshore wind farm capital cost is double of onshore, but:

- Grid connection is limited resource. That applies in Estonia and elsewhere. 1,000 MW offshore wind produces electricity of 2,000 MW onshore wind, and room remains for other generation capacity to connect (gas, biomass etc)
- Baltic Offshore Wind is „system friendly“ as +25 m/s wind that cause sudden tripping, are not frequent
- Offshore wind is stable – combustible fuels do not have to be used as often for balancing
- Estonian Offshore Wind speed is fully comparable to North Sea

- Onshore wind most expensive section is Rotor-Nacelle-Assembly (RNA)
- **Offshore wind most expensive section is Support Structure, as proportions have changed**
- Use of North Sea Heavy Lift Vessels (HLV) for RNA installation should be avoided
- Passive monopile typology will not survive drifting ice in more than 10-15 m depth
- Active (ice management) monopile typology could survive any depth, but ice management has to be dependable
- Passive pyramidal GBS will survive in deep water



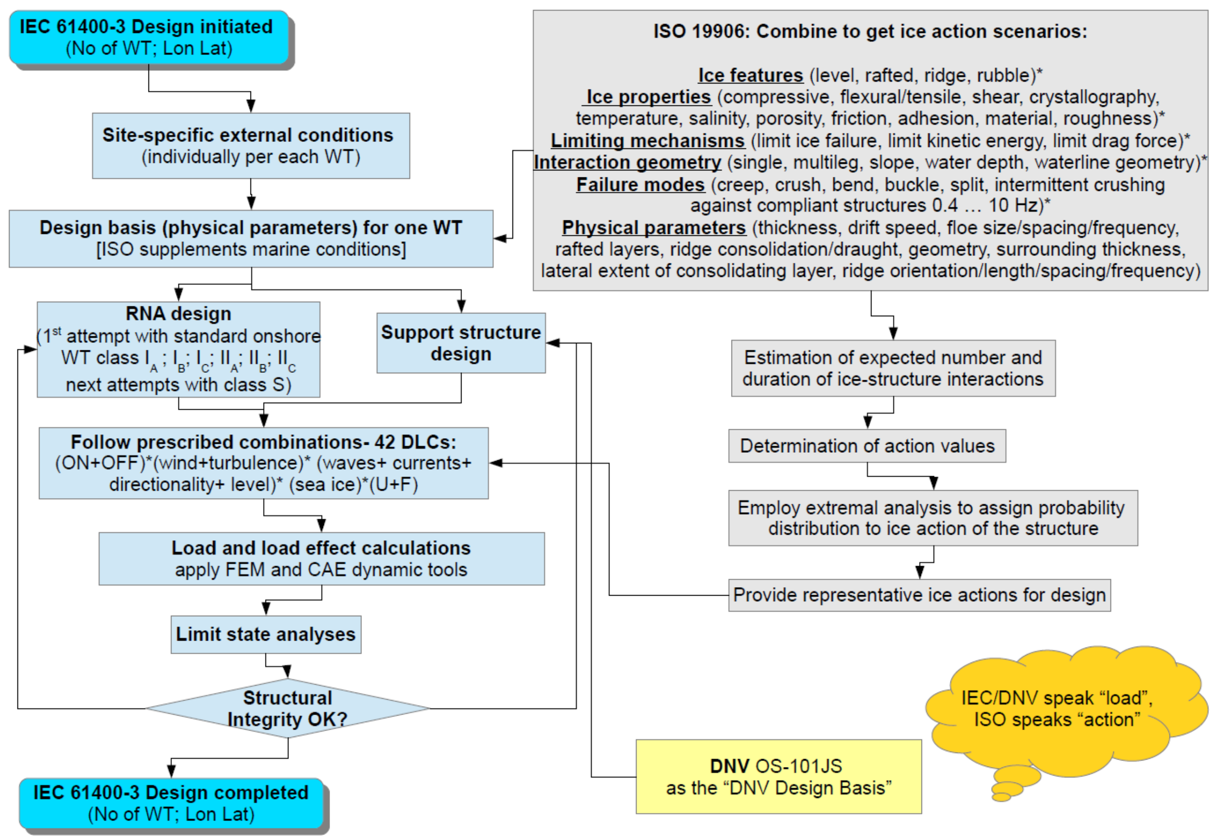
Tuulepargi tüüp	Tuuliku klass	Kandetarindite hind	Turu olukord	Võimalused Eesti ettevõtetele
Maa (WT)	I_a kuni III_c (S)	Ca 0.3 M€/MW	**Väga vähe ruumi** uutele tulijatele	Tugevad ettevõtted leiavad alati niśši (ABB)
Meri (WT/OWT); jäävaba, kuni 60 m sügavus	I_a kuni II_c, S	Ca 1 M€/MW	**Väga vähe ruumi** uutele tulijatele	Tugevad ettevõtted leiavad alati niśši (BLRT Marketex)
Meri (OWT/SIWT); kinnisjää (* (30 cm)	I_a kuni II_c, S	Samas klassis maismaaga	**Turul on niśše**; Soome: Kemi Ajos demo	Kandetarindite projekteerimine, valmistamine ja koostamine
Meri (OWT/SIWT); kinnisjää (50-80 cm)	I_a (S)	Ca 1 M€/MW	**Turul on niśše**; Soome: Pori Tahkoluoto demo 9 m; Rootsi: Norströmsgrundi tuletorn 15 m	Kandetarindite projekteerimine, valmistamine ja korrashoid (** ice management); SIWT terviklik projekteerimine, valmistamine ja koostamine
Meri (SIWT); kinnisjääd piirkonnas ilma tuulikuteta ei teki (***, 15-60 m sügavus	S (I_a)	?	**Turg on tühi**, demo puudu	Jääuuringute konfidentsiaalne info; Innovatiivsed lahendused; Kandetarindite projekteerimine ja valmistamine; SIWT terviklik projekteerimine, valmistamine ja koostamine
Meri (SIWT_F), kinnisjääd ei teki, 60+ m sügavus	?	?	**Turg on tühi**, demo puudu	SIWT_F kontseptsioon

(* vähemalt 30 cm jää, mis jääb liikumatuks tugevate tuultega
(** aktiivsed meetmed jääkoormuste piiramiseks
(*** tuulepargisisene tehiskinnisjää on võimalik

In the case of the rotor – nacelle assembly, which may have been designed initially on the basis of a standard wind turbine class as defined in IEC 61400-1**, it shall be demonstrated that the offshore site-specific external conditions do not compromise the structural integrity.**
The demonstration shall comprise a comparison of loads and deflections **- to verify that no mechanical interference between blade and tower will occur** - calculated for the **specific offshore wind turbine site conditions** with those calculated during initial design, taking account of the **reserve margins** and the **influence of the environment** on structural resistance and the appropriate **material selection**. The calculation of loads and deflections shall also take account of the influence of **site-specific soil properties – liquefaction** - on the dynamic properties of an offshore wind turbine, as well as potential long term time variation of these dynamic properties due to seabed movement and scour.

The design process is iterative and shall incorporate load and load effect calculations for the complete wind turbine comprising the integrated support structure and rotor – nacelle assembly.

ISO and DNV offer input to IEC iterative design process



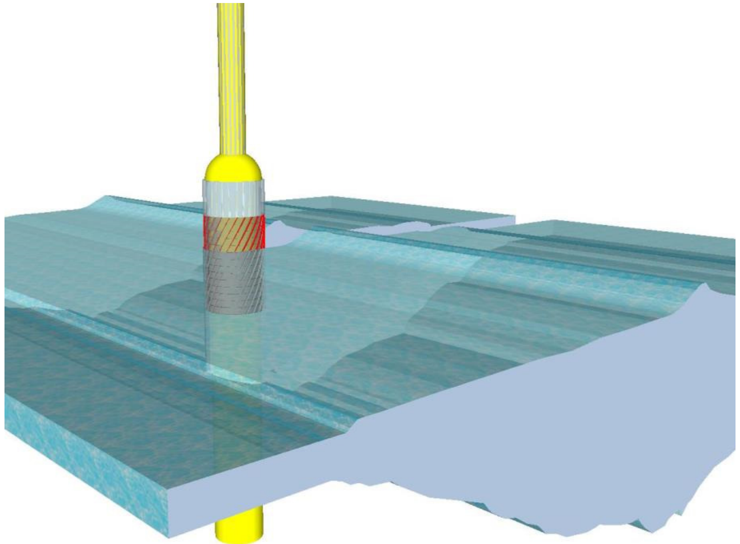
SIWT differs from North Baltic Sea Offshore Lighthouses : it has multi-MW electrical power for emergency use.

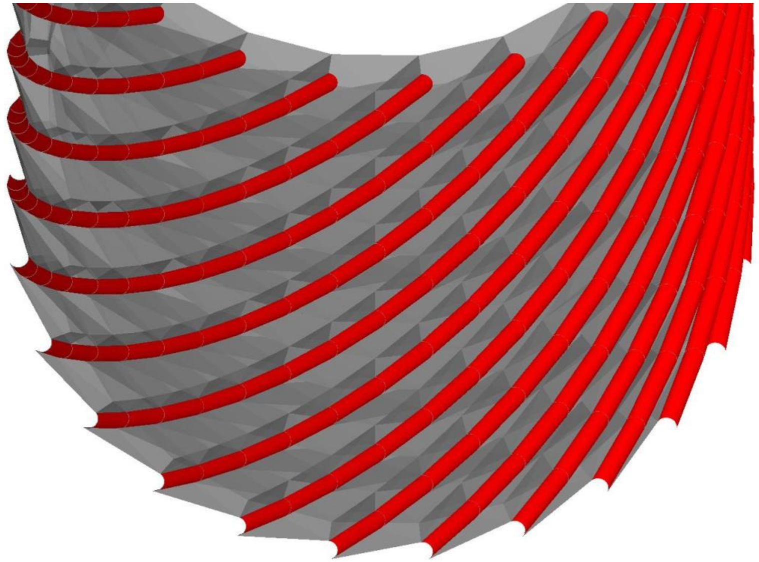
Power to cutting area – of incoming ice-drift, is many times more than needed for the job. Different ice management tools are available, most promising are mechanical cutting and steam blasting

Example of mechanical cutting:

Sleeve Cutter is fitted on Monopile. VT type is „Vertical Axis“ (VAWT). Generator/Motor type is „Brushless Outer Rotor PMG“. Sleeve Cutter is „Clutch Coupled & Directly Driven by Outer Rotor PMG“, which in turn is „Directly Driven by VAWT Rotor Assembly“. Optional Reverse Gear. Waste heat from „Liquid Cooled Inner Stator“ keeps moving parts unfrozen.

Forthcoming (CD in June 2014) IEC 61400-3-2 „Design requirements for floating offshore wind turbines“ will open up development niche for VAWTs that have advantages in floating use and in sea ice environment

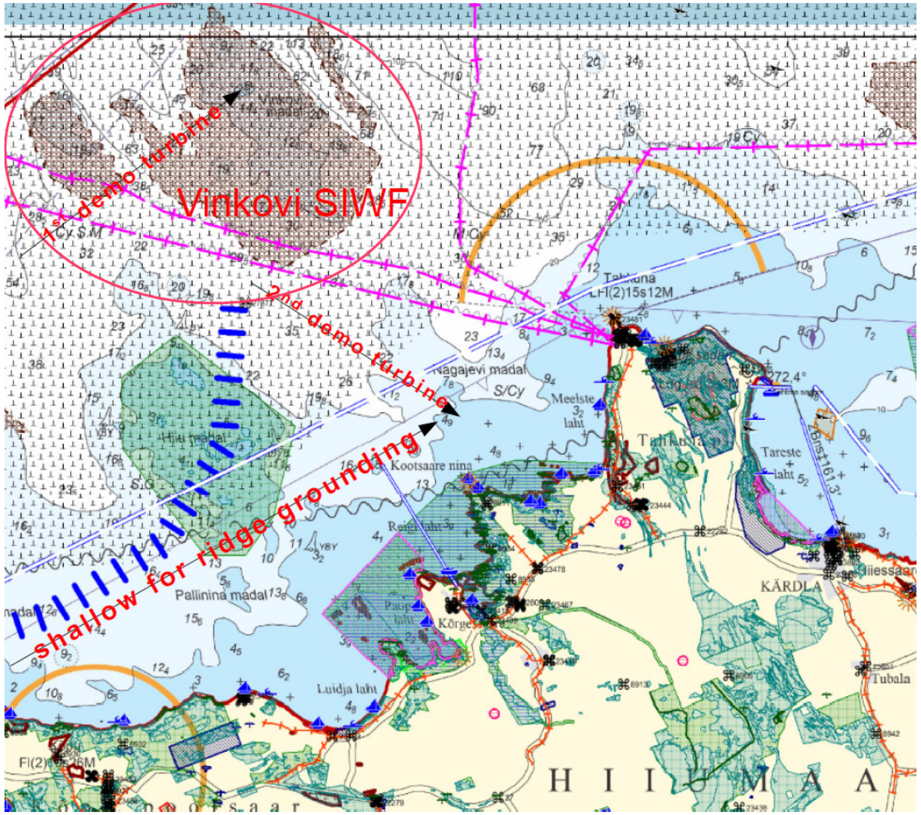




Nearshore alternative is preferable for rigid support structure with turbine:
- Ridge management
- Access / EER training using different vessels
- Frequent icing
- Shallow ground in the 500 – 1000 m vicinity to study landfasting
- cheaper grid connection

Farshore alternative is preferable for studying compliant support structure in 20 m depth:
- First years without turbine (incl. tower&dummy load)
- Later years with grid connected turbine

2 alternatives for DEMO SIWT



Map:
http://www.hiiumeri.artes.ee/

SIWFs should be placed between 5 – 10 km from shore – forthcoming Estonian regional MSPs must allow turbines return closer to shore

SIWT should be in near-landfast area where the inter-turbine artificial landfast ice connects with the shallows and coastline

SIWF's cost of energy must be competitive - pushing turbines out of coastal property owners' (minority) view is pushing up everyone's electricity bill

Finland is excellent example for Estonian planners with many developments close to shore

Landscape architects should be consulted to place turbines pleasantly

Photo: Pori Tahkoluoto, Finland nearshore SIWT visited with EWPC

Artificial landfast ice is maintained when required crushing force - F_G at vertical support structures is higher than rubbling force - F_B beyond the perimeter of the SIWF

Rubbling will be facilitated by amphibious craft with special drawbar trencher („icebreaker“)

The gain is increased SIWT uptime in non-vibrating conditions, and comfortable ice road access

The support structure is not designed cheap – the structure is designed to crush all incoming ice in case when ice management is not successful

SIWT Interval m	Icebreaker channel pressure-side m (covers half perimeter)	h m	$R_{ISO19906, 99\% confidence}$	p_D MN/m	F_B MN		SIWT Quantity	F_D MN	Windfarm: F_D MN	h m	D m	p_T MN/m	F_T MN	Windfarm: F_T MN	D/h	D*h m²	C_R MPa	k_1 for shape	k_2 for contact	k_3 for aspect ratio	F_G MN IEC61400-3	Windfarm: F_G MN	Windfarm: $F_{COMBINATION}$ MN
1,000	20,000	0.5	10	0.020	**400**	SIWTs, perimeter	36	1.04	**37**	0.5	**10**	0.20	2.0	**72**	20	5.0	3.0	0.9	1.5	1.12	22.6	**815**	**706**
1,000		0.5				SIWTs, interior	64	1.04	**67**	0.5	**7**	0.20	1.4	**90**	14	3.5	3.0	0.9	1.5	1.16	16.5	**1,057**	**901**
						total	*100*															$F_{COMBINATION}$	**1,606**
							Less turbines				Small D											F_B	**400**
1,000	14,000	0.5	10	0.024	**340**	SIWTs, perimeter	24	1.04	**25**	0.5	**5**	0.20	1.0	**24**	10	2.5	3.0	0.9	1.5	1.22	12.4	**298**	**249**
1,000		0.5				SIWTs, interior	25	1.04	**26**	0.5	**5**	0.20	1.0	**25**	10	2.5	3.0	0.9	1.5	1.22	12.4	**310**	**259**
						total	*49*															$F_{COMBINATION}$	**508**
		Thicker ice									Medium D											F_B	**340**
1,000	14,000	0.8	10	0.044	**611**	SIWTs, perimeter	24	1.04	**25**	0.8	**7**	0.20	1.4	**34**	8.75	5.6	3.0	0.9	1.5	1.25	28.4	**682**	**624**
1,000		0.8				SIWTs, interior	25	1.04	**26**	0.8	**7**	0.20	1.4	**35**	8.75	5.6	3.0	0.9	1.5	1.25	28.4	**711**	**650**
						total	*49*															$F_{COMBINATION}$	**1,274**
Less interval											Big D							Rectangle				F_B	**611**
750	10,500	0.8	10	0.051	**535**	SIWTs, perimeter	24	0.59	**14**	0.8	**10**	0.20	2.0	**48**	12.5	8.0	3.0	1	1.5	1.18	42.6	**1,022**	**960**
750		0.8				SIWTs, interior	25	0.59	**15**	0.8	**10**	0.20	2.0	**50**	12.5	8.0	3.0	1	1.5	1.18	42.6	**1,065**	**1,000**
						total	*49*															$F_{COMBINATION}$	**1,961**
			Rising T effect?									Spring					Spring		Spring			F_B	**535**
750	10,500	0.8	10	0.017	**178**	SIWTs, perimeter	24	0.59	**14**	0.8	**10**	0.00	0.0	**0**	12.5	8.0	1.0	1	0.5	1.18	4.7	**114**	**100**
750		0.8				SIWTs, interior	25	0.59	**15**	0.8	**10**	0.00	0.0	**0**	12.5	8.0	1.0	1	0.5	1.18	4.7	**118**	**104**
						total	*49*															$F_{COMBINATION}$	**203**
																						F_B	**178**

Abbreviations:

- F_B **Ridge building load**
- F_D **Wind drag load, 20 m/s wind, 0.6 m/s drift and 0.6 m/s current, all co-directional**
- F_T **Thermal expansion load, freshwater ice**
- F_G **Crushing load against vertical geometry**
- $F_{COMBINATION}$ **equals** F_G **less** F_T **less** F_D

Remark:
The Table describes 5 different wind farm cases. A case may use different waterline diameter on perimeter versus interior turbines.

The access craft of choice

- Water to ice transitions with complete versatility and consistency
- Crossing shallow water, mixed ice water, ice rubble fields and side slope
- Ability to climb vertical steps and steep grades (ice and beach)
- Ice breaking, ice clearing and ice management
- Waterjet bollard pull of 3.2 T in water and track powered drawbar pull of 31.5 T on solid ice
- Operation in all severe weather conditions (wind, sea state, poor visibility and low temperatures)
- Watertight compartments in both Front and Rear Units Survivability
- Insulated Hulls and Decks in the unlikely event both engines fail
- 2 Units, 2 Waterjets, 2 Track Systems and 2 Engine
- Craft is tested and certified by USCG, one of the major maritime authority, and approved for 52 people
- Internal craft's space (capacity) in both Units allow to accommodate crew and/or repair/service work shop with tools and spares

<u>Photos</u> provided by Gary Birchenko:
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www.arktoscraft.com

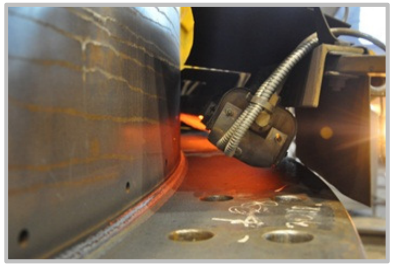
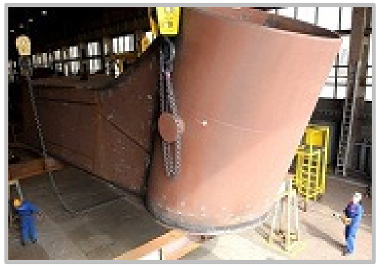
An ARKTOS Evacuation and Service Craft (spare parts shop front, 6 technicians back) climbing from deep water up a 1m+ vertical wall of ice onto an ice floe


An ARKTOS Evacuation Craft (USCG approved for 52 people) operating in mixed ice and water conditions

BLRT Marketex, Tallinn, Estonia based international ship-building company should work not only for North Sea wind farms:

- Serial production of heavy steel components up to 200 tons
- Transition Pieces for Jackets
- Pile Sleeves for Jackets and Tripods
- Upper Box Girder Sections for Tripiles
- Other heavy components to allow more effective assembly and welding




Photos:
www.marketex.ee

Estonian companies and institutes should focus on:

- Understanding sea ice and wind turbine interactions and integrated design requirements
- Developing integrated design tools for RNA-Support Structure structural integrity determination
- Developing NEW standard for SIWT, synthesized from IEC 61400 and ISO 19900 family
- Providing taylor-made services to Estonian + 1.5 GW offshore windfarm pipeline
- Collaborating with Swedish and Finnish companies and institutes to solve industry problems common for all Baltic Sea sub-arctic areas
- Participating worldwide: Great Lakes of US & Canada; Bohai Sea of China

List of Estonian companies can be found at Estonian Wind Power Association homepage: www.tuuleenergia.ee

Thank you for your attention!