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Supplementary Materials

A life cycle decision framework of China offshore wind turbines with ANP-Intuitionistic fuzzy TOPSIS method

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This Supplementary Materials includes:

Supplementary Tables 1 and 2: The relevant information in identifying alternative life-cycle design schemes.

Supplementary Tables 3 and 4: The relevant data and calculation results in determination of the correlation and weights of criteria.

Supplementary Tables 5-7: The relevant data and calculation results in determination for the life cycle design scheme of green offshore wind turbine.

Supplementary Table 1. The structural form expression of FSMPT model of design schemes

Design schemes	Structural form expression
A1	S1 + S2 + S4 + S5 + S6 + S10 + S11 + S14 + S17 + S18 + S20
A2	S1 + S2 + S4 + S5 + S6 + S12 + S13 + S14 + S16 + S19 + S20
A3	S1 + S2 + S7 + S8 + S9 + S12 + S13 + S15 + S16 + S18 + S21
A4	S1 + S3 + S7 + S8 + S9 + S12 + S13 + S14 + S17 + S18 + S21
A5	S1 + S3 + S7 + S8 + S9 + S12 + S13 + S15 + S16 + S18 + S20
A6	S1 + S2 + S4 + S5 + S6 + S12 + S13 + S14 + S16 + S18 + S21

Supplementary Table 2. Design schemes FSMPT model life cycle information

Function (F)	Subfunction	Structure (S)	Material (M)	Process (P)	Transport (T)
Energy conversion	Wind energy converts mechanical energy	Blade (S1)	Glass fibre	Layup, perfusion	1,910 km
Variable pitch	Electric variable pitch	Variable pitch generator (S2)	Copper	Smelting, desulfurization	1,015 km
	Hydraulic variable pitch	Hydraulic cylinder (S3)	Carbon steel	Rolling, grinding	2,090 km
Drive	Doubly-fed	Doubly-fed gear box (S4)	Alloy steel	Forge, heat treatment, machining	1,800 km
			Cast iron	Casting, machining	1,260 km
		Doubly-fed generator (S5)	Copper	Smelting, desulfurization	2,000 km
			Silicon steel strip	Punching, welding	1,450 km
		Doubly-fed main shaft (S6)	cast iron	Casting, machining	1,190 km
	Semi-direct drive	Semi-direct drive gear box (S7)	Alloy steel	Forge, heat treatment, machining	1,800 km
			Cast iron	Casting, machining	1,260 km
		Semi-direct drive generator (S8)	Copper	Smelting, desulfurization	2,000 km
			Silicon steel strip	Punching, welding	1,450 km
		Semi-direct drive main shaft (S9)	Alloy steel	Forge, heat treatment, milling	1,190 km
Yaw	Rolling yaw	Rolling yaw bearing (S10)	Alloy steel	Forge, heat treatment	1,585 km
		Rolling yaw brake (S11)	Cast iron	Casting, milling	930 km
	Sliding yaw	Sliding yaw	Alloy steel	Forge, heat	1,585 km

		gear ring (S12)		treatment	
		Sliding yaw calipers (S13)	Alloy steel	Forge, machining	1,190 km
Support	Blade support	Star hub (S14)	Cast iron	Casting, machining	1,190 km
		Spherical hub (S15)	Cast iron	Casting, machining	1,190 km
	Engine room support	Welding main frame (S16)	Carbon steel	Welding, machining	755 km
		Casting main frame (S17)	Cast iron	Casting, machining	1,190 km
		Welding generator bottom frame (S18)	Carbon steel	Welding, machining	755 km
		Casting generator bottom frame (S19)	Cast iron	Casting, machining	1,190 km
	Tower support	Steel tower (S20)	Carbon steel	Welding, machining	1,655 km
		Mixing tower (S21)	Concrete	Prefabrication	1,655 km

Supplementary Table 3. Questionnaire on correlation of evaluation criteria for the life cycle of offshore wind turbine

Criteria		C1					C2						C3							C4										C5				
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33
C1	S1	√		√	√	√																								√		√	√	√
	S2		√	√																											√	√	√	√
	S3	√	√	√	√	√			√						√																	√	√	√
	S4	√		√	√						√					√										√	√			√	√	√	√	√
	S5	√		√		√																												√
C2	S6						√		√	√	√	√																						
	S7							√	√	√	√	√																						
	S8			√			√	√	√	√	√	√			√		√					√	√	√	√	√	√			√	√	√	√	√
	S9						√	√	√	√	√	√										√	√	√	√	√	√			√	√	√	√	√
	S10				√		√	√	√	√	√	√				√										√	√						√	
	S11						√	√	√	√	√	√																						
C3	S12												√			√		√	√															
	S13													√		√		√	√															
	S14			√					√						√	√																√	√	
	S15				√						√		√	√	√	√											√							
	S16								√								√																	
	S17												√	√				√	√															
	S18												√	√				√	√															
C4	S19																			√						√	√	√						
	S20																				√					√	√	√						
	S21								√	√												√	√			√	√							
	S22								√	√												√	√			√	√							
	S23								√	√														√		√	√					√	√	
	S24								√	√															√	√	√					√	√	
	S25				√				√	√	√									√	√	√	√	√	√	√	√							
	S26				√				√	√	√					√				√	√	√	√	√	√	√	√					√		
	S27																			√	√							√	√					
	S28																											√	√					
C5	S29	√			√				√	√																				√		√	√	√
	S30		√		√				√	√																					√	√	√	√
	S31	√	√	√	√				√	√					√									√	√		√			√	√	√	√
	S32	√	√	√	√				√	√	√				√									√	√					√	√	√	√
	S33	√	√	√	√	√			√	√																				√	√	√	√	√

Supplementary Table 4. Criteria and sub-criteria weights for offshore wind turbines

Criteria	Weights	Sub-criteria	Sub-criteria weights
C1 Raw material acquisition phase	0.2914	S1 (Raw material acquisition phase) energy consumption	0.0300
		S2 (Raw material acquisition phase) Resource consumption	0.0244
		S3 Material acquisition technology level	0.0757
		S4 Raw material cost	0.1446
		S5 (Raw material acquisition phase) Greenhouse gas emissions	0.0166
C2 Production and manufacturing phase	0.4147	S6 (Production and manufacturing phase) energy consumption	0.0296
		S7 (Production and manufacturing phase) Resource consumption	0.0291
		S8 Manufacturing process complexity	0.1051
		S9 Manufacturing technology level	0.0324
		S10 Manufacturing process cost	0.1679
		S11 (Production and manufacturing phase) Greenhouse gas emissions	0.0506
C3 Transportation and installation phase	0.1099	S12 (Transportation and installation phase) energy consumption	0.0018
		S13 (Transportation and installation phase) Resource consumption	0.0015
		S14 The technical complexity of transportation and installation	0.0395
		S15 Transportation and installation cost	0.0617
		S16 Degree of social need	0.0040
		S17 (Transportation and installation phase) Ecological impact	0.0005
		S18 (Transportation and installation	0.0008

		phase) Greenhouse gas emissions	
C4 Operation and maintenance phase	0.0468	S19 (Operation and maintenance phase) energy consumption	0.0003
		S20 (Operation and maintenance phase) Resource consumption	0.0005
		S21 Turbine output power	0.0042
		S22 Ease of maintenance	0.0033
		S23 System conversion rate	0.0043
		S24 Operational safety	0.0021
		S25 Operating cost	0.0048
		S26 Sales profit	0.0268
		S27 (Operation and maintenance phase) Ecological impact	0.0002
		S28 Noise and visual impact	0.0003
C5 Disassembly and disposal phase	0.1372	S29 Recovery of energy	0.0131
		S30 Resource recovery rate	0.0121
		S31 Recovery technology level	0.0327
		S32 Recovery cost	0.0424
		S33 Recovery of greenhouse gas emissions	0.0368

Supplementary Table 5. DM weights

	DM1	DM2	DM3
Significance	VS	M	I
Linguistic terms	(0.90, 0.10, 0)	(0.50, 0.45, 0.05)	(0.35, 0.60, 0.15)
DM weights	0.4914	0.2874	0.2213

Supplementary Table 6. Rating of alternative design scheme

Criteria	Design scheme	DMs		
		DM1	DM2	DM3
Raw material acquisition phase	A1	M	H	MH
	A2	H	H	VVH
	A3	MH	VVH	VH
	A4	VVH	VH	VH
	A5	VH	VH	MH
	A6	VH	VVH	H
Production and manufacturing phase	A1	MH	VH	VVH
	A2	H	VH	H
	A3	VVH	MH	H
	A4	H	H	H
	A5	H	VVH	VVH
	A6	VVH	H	VH
Transportation and installation phase	A1	MH	M	MH
	A2	MH	H	VVH
	A3	H	H	H
	A4	VVH	VVH	MH
	A5	EH	VH	MH
	A6	H	MH	MH
Operation and maintenance phase	A1	EH	MH	VVH
	A2	VH	VH	VH
	A3	VH	VVH	MH
	A4	MH	VVH	M
	A5	H	VVH	VH
	A6	VVH	VVH	EH
Disassembly and disposal phase	A1	VVH	VH	VH
	A2	H	MH	H
	A3	MH	M	MH
	A4	VH	VH	H
	A5	VVH	EH	H
	A6	VVH	VH	VVH

Supplementary Table 7. Evaluation of design scheme based on intuitionistic fuzzy number

Criteria	Design scheme	DMs		
		DM1	DM2	DM3
Raw material acquisition phase	A1	[0.50, 0.40]	[0.70, 0.20]	[0.60, 0.30]
	A2	[0.70, 0.20]	[0.70, 0.20]	[0.90, 0.10]
	A3	[0.60, 0.30]	[0.90, 0.10]	[0.80, 0.10]
	A4	[0.90, 0.10]	[0.80, 0.10]	[0.80, 0.10]
	A5	[0.80, 0.10]	[0.80, 0.10]	[0.60, 0.30]
	A6	[0.80, 0.10]	[0.90, 0.10]	[0.70, 0.20]
Production and manufacturing phase	A1	[0.60, 0.30]	[0.80, 0.10]	[0.90, 0.10]
	A2	[0.70, 0.20]	[0.80, 0.10]	[0.70, 0.20]
	A3	[0.90, 0.10]	[0.60, 0.30]	[0.70, 0.20]
	A4	[0.70, 0.20]	[0.70, 0.20]	[0.70, 0.20]
	A5	[0.70, 0.20]	[0.90, 0.10]	[0.90, 0.10]
	A6	[0.90, 0.10]	[0.70, 0.20]	[0.80, 0.10]
Transportation and installation phase	A1	[0.60, 0.30]	[0.50, 0.40]	[0.60, 0.30]
	A2	[0.60, 0.30]	[0.70, 0.20]	[0.90, 0.10]
	A3	[0.70, 0.20]	[0.70, 0.20]	[0.70, 0.20]
	A4	[0.90, 0.10]	[0.90, 0.10]	[0.60, 0.30]
	A5	[1.00, 0.00]	[0.80, 0.10]	[0.60, 0.30]
	A6	[0.70, 0.20]	[0.60, 0.30]	[0.60, 0.30]
Operation and maintenance phase	A1	[1.00, 0.00]	[0.60, 0.30]	[0.90, 0.10]
	A2	[0.80, 0.10]	[0.80, 0.10]	[0.80, 0.10]
	A3	[0.80, 0.10]	[0.90, 0.10]	[0.60, 0.30]
	A4	[0.60, 0.30]	[0.90, 0.10]	[0.50, 0.40]
	A5	[0.70, 0.20]	[0.90, 0.10]	[0.80, 0.10]
	A6	[0.90, 0.10]	[0.90, 0.10]	[1.00, 0.00]
Disassembly and disposal phase	A1	[0.90, 0.10]	[0.80, 0.10]	[0.80, 0.10]
	A2	[0.70, 0.20]	[0.60, 0.30]	[0.70, 0.20]
	A3	[0.60, 0.30]	[0.50, 0.40]	[0.60, 0.30]
	A4	[0.80, 0.10]	[0.80, 0.10]	[0.70, 0.20]
	A5	[0.90, 0.10]	[1.00, 0.00]	[0.70, 0.20]
	A6	[0.90, 0.10]	[0.80, 0.10]	[0.90, 0.10]