

Table S1 Related specification document of BIPV

Serial number	Name of the normative document	Document number
1	The Code of Practice for Operation and Maintenance of Photovoltaic Building Integration Systems	JGJ/T 264-2012
2	Technical Specifications for the Application of Solar Photovoltaic Systems in Civil Buildings	JGJ 203-2010
3	Technical Specifications for Centralized Operation and Maintenance of Distributed Photovoltaic Power Generation Systems	GB/T 38946-2020
4	Electrical Design specifications for Solar photovoltaic glass curtain wall	JGJ/T 365-2015
5	General technology of photovoltaic solar shading components for buildings	JG/T 482-2015
6	General Technical Requirements for the Components of Photovoltaic Building	JG/T 492-2016
7	Flexible thin-film photovoltaic modules for buildings	JG/T 535-2017
8	Building Integrated Photovoltaic (BIPV) Module Cell Rated Operating Temperature Test Methods	GB/T 37052-2018
9	Lightning protection Technical specifications for photovoltaic building integrated system	GB/T 36963-2018
10	Photovoltaic solar shading panels for buildings	GB/T 37268-2018
11	Technical standards for Building a photovoltaic system	GB/T 51368-2019
12	Architectural solar photovoltaic laminated glass	GB/T 29551-2013
13	General Specifications for Energy Efficiency and use of Renewable Energy in Buildings	GB 55015-2021
14	Technical requirements for grid-connected photovoltaic systems	GB/T 19939-2005
15	Photovoltaic devices Part 2: Requirements for standard solar cells	GB/T 64952-1996
16	Technical regulations for the integration of solar photovoltaic power generation systems and buildings	CECS 418-2015
17	Technical regulations governing Photovoltaic power generation system access to the distribution network	GBT 29319-2012
18	Technical Guidelines for integrated application of Solar Photovoltaic and building	CJS01-2010
19	Standardization conditions for the Photovoltaic manufacturing industry	Ministry of Industry and Information Technology (abbr.)
20	Design Specifications for a Photovoltaic Power Plant	GB50797
21	Specifications for Distributed power grid-connected operation control	GB/T33592
22	Technical regulations governing Photovoltaic power generation system access to the distribution network	GB/T29319
23	Acceptance criteria for photovoltaic and building-integrated power generation systems	GB/T 37655-2019
24	Technical standards for solar heating and heating engineering	GB5 0495-2019
25	Uniform Standards for Quality Acceptance of Building Construction	GB 50300-2013

Table S2 Results of the first round of Expert Survey Method risk factor scores

Risk number	Risk factors	average value	standard deviation	coefficient of variation	result of judgment
1	Consumer acceptance	4.10	0.57	0.14	√
2	BIPV Market Supply	3.77	0.50	0.13	√
3	Project finance	4.23	0.53	0.13	√
4	Project location	4.13	0.44	0.11	√
5	Level of regional development	4.00	0.57	0.14	○
6	Geographical conditions of the project	3.93	0.53	0.13	○
7	Incremental cost	3.87	0.67	0.17	√
8	Energy conservation and environmental benefits	3.34	0.27	0.08	×
9	Feed-in tariff	3.93	0.62	0.16	√
10	Risk of changes in policies and regulations	4.03	0.79	0.20	√
11	Master Plan Design	4.03	0.61	0.15	√
12	Load forecasting	3.57	0.56	0.16	√
13	Poor program design	4.10	0.63	0.15	√
14	Project Integration Design	4.07	0.53	0.13	√
15	Tendering methods and contractor qualification	3.53	0.58	0.16	√
16	Inadequate design codes and standards	3.97	0.55	0.14	√
17	Security management	3.67	0.67	0.18	√
18	Relaying protection measures	3.50	0.38	0.11	○
19	Inadequate quality acceptance criteria	3.70	0.53	0.14	√
20	Quality management	3.10	0.34	0.11	○
21	Cost management	3.53	0.69	0.20	√
22	Progress management	3.57	0.53	0.15	√
23	Contract management	3.67	0.62	0.17	√
24	Technical risk of PV equipment maintenance	3.60	0.57	0.16	√

Table S6 Risk assessment index

Standardized layer	Serial number	Indicator layer
Pre-decision stage exposures R1	R11	Risk of inadequate policies and regulations (
	R12	BIPV market supply risk
	R13	Project finance risk
	R14	Site selection risk
	R15	Risk of consumer acceptance
	R16	Feed-in tariff risk
	R17	Incremental cost risk
Preparation and design phase exposures R2	R21	Risk of poor project master planning
	R22	Risk of load forecasting accuracy
	R23	Risk of poor project program design
	R24	Risk to the level of integrated project design
	R25	Tendering methods and contractor qualification risks
	R26	Risk of not improving design codes, standards and related atlases
	R31	Construction safety risk
Project implementation phase exposures R3	R32	Risk of inadequate quality acceptance criteria
	R33	Risks in construction cost management
	R34	Risks of construction schedule management
	R35	Construction contract management risk
	R41	Risk of not having well-established technical standards for PV equipment maintenance
Operation and maintenance phase exposures R4	R42	Grid acceptance and commissioning risk
	R43	Risk of regular billing for electricity
	R44	Risk of inoperability due to natural disasters

Table S7 Direct influence matrix

	R11	R12	R13	R14	R15	R16	R17	R21	R22	R23	R24	R25	R26	R31	R32	R33	R34	R35	R41	R42	R43	R44
R11	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R12	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	1	0	0
R13	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R14	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	1
R15	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
R16	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R17	3	1	1	1	0	1	0	0	0	0	0	1	2	0	2	0	0	1	0	0	0	0
R21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
R22	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
R23	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	1	1
R24	1	0	0	0	1	0	0	0	0	2	0	1	0	1	0	0	1	1	0	0	0	0
R25	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	2	0	0	0	0
R26	0	0	0	0	0	0	0	0	0	2	3	0	0	1	1	0	0	0	1	0	0	0
R31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
R32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
R33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
R34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
R35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
R41	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1
R42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
R43	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R44	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1	0

Table S8 The Gauge influence matrix

	R11	R12	R13	R14	R15	R16	R17	R21	R22	R23	R24	R25	R26	R31	R32	R33	R34	R35	R41	R42	R43	R44
R11	0	0	0.07	0.07	0	0	0.07	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R12	0	0	0.07	0	0	0.07	0	0	0	0.07	0	0	0	0	0	0.07	0.07	0	0	0.07	0	0
R13	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R14	0.21	0	0	0	0	0	0	0.14	0	0	0	0	0	0	0	0.07	0	0	0	0	0	0.07
R15	0	0	0.21	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0	0	0	0	0	0
R16	0	0	0.21	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R17	0.21	0.07	0.07	0.07	0	0.07	0	0	0	0	0	0.07	0.14	0	0.14	0	0	0.07	0	0	0	0
R21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.07	0	0	0.14	0	0
R22	0	0	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
R23	0	0	0	0	0.07	0	0	0	0	0	0	0	0	0.07	0	0.07	0.07	0	0	0.07	0.07	0.07
R24	0.07	0	0	0	0.07	0	0	0	0	0.14	0	0.07	0	0.07	0	0	0.07	0.07	0	0	0	0
R25	0.07	0	0	0	0	0	0	0	0	0	0.21	0	0	0	0	0	0	0.14	0	0	0	0
R26	0	0	0	0	0	0	0	0	0	0.14	0.21	0	0	0.07	0.07	0	0	0	0.07	0	0	0
R31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.07	0.07	0	0	0	0
R32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
R33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0	0	0	0	0
R34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0	0	0	0
R35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0
R41	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.14	0.07
R42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0
R43	0	0	0.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R44	0.07	0	0	0.07	0	0	0	0	0	0	0	0	0	0.07	0	0.07	0.07	0	0	0	0.07	0

Table S9 The Comprehensive influence matrix

	R11	R12	R13	R14	R15	R16	R17	R21	R22	R23	R24	R25	R26	R31	R32	R33	R34	R35	R41	R42	R43	R44
R11	0.05	0.01	0.08	0.08	0	0.01	0.07	0.09	0	0	0	0.01	0.01	0	0.01	0.01	0.01	0.01	0	0.02	0.01	0.01
R12	0.02	0	0.09	0.01	0.01	0.07	0	0	0	0.07	0	0	0	0.01	0	0.08	0.08	0.01	0	0.01	0.01	0.01
R13	0.15	0	0.01	0.01	0	0	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R14	0.23	0	0.02	0.02	0	0	0.02	0.16	0	0	0	0	0	0.01	0	0.09	0.02	0	0	0	0	0.07
R15	0.03	0	0.22	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.01	0	0	0	0	0
R16	0.07	0	0.24	0.15	0	0	0	0.03	0	0	0	0	0	0	0	0.01	0	0	0	0	0.07	0.01
R17	0.27	0.07	0.13	0.10	0.01	0.08	0.02	0.03	0	0.05	0.05	0.08	0.15	0.02	0.16	0.02	0.02	0.09	0.01	0.04	0.09	0.01
R21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.08	0.01	0	0.14	0.01	0
R22	0.01	0	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.01	0
R23	0.01	0	0.03	0.01	0.07	0	0	0	0	0	0	0	0	0.08	0	0.09	0.09	0.01	0	0.07	0.08	0.07
R24	0.09	0	0.03	0.01	0.09	0	0.01	0.01	0	0.22	0.02	0.07	0	0.09	0	0.04	0.11	0.10	0	0.02	0.02	0.02
R25	0.09	0	0.01	0.01	0.02	0	0.01	0.01	0	0.05	0.22	0.02	0	0.02	0	0.01	0.03	0.16	0	0	0	0
R26	0.09	0	0.02	0	0.03	0	0	0	0	0.26	0.22	0.02	0	0.11	0.07	0.03	0.05	0.03	0.07	0.04	0.03	0.02
R31	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.08	0.08	0	0	0	0
R32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.21	0.02	0
R33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.07	0.01	0	0	0	0
R34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.01	0.07	0	0	0	0
R35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.07	0.01	0	0	0	0
R41	0.09	0	0.04	0.01	0	0	0.01	0.01	0	0	0	0	0	0.01	0	0.01	0.01	0	0	0.07	0.15	0.07
R42	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0
R43	0.03	0	0.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R44	0.09	0	0.02	0.08	0	0	0.01	0.02	0	0	0	0	0	0.07	0	0.09	0.09	0.01	0	0	0.07	0.01

Table S10 The Unweighted super matrix

	R11	R12	R13	R14	R15	R16	R17	R21	R22	R23	R24	R25	R26	R31	R32	R33	R34	R35	R41	R42	R43	R44
R11	0	0	1.00	1.00	0	0	0.53	0	0	0	0.50	1.00	0	0	1.00	0	0	0	0.67	0	0	0.50
R12	0	0	0	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R13	0.33	0.50	0	0	1.00	0.75	0.12	0	1.00	0	0	0	0	0	0	0	0	0	0	0	1.00	0
R14	0.33	0	0	0	0	0.25	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50
R15	0	0	0	0	0	0	0	0	0	1.00	0.50	0	0	0	0	1.00	1.00	0	0	0	0	0
R16	0	0.50	0	0	0	0	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R17	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R21	1.00	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	0	0
R23	0	1.00	0	0	0	0	0	0	1.00	0	0.50	0	0.50	0	0	0	0	0	0	0	0	0
R24	0	0	0	0	0	0	0	0	0	0	0	1.00	0.50	0	0	0	0	0	0	0	0	0
R25	0	0	0	0	0	0	0	0	0	0	0.50	0	0	0	0	0	0	0	0.01	0	0	0
R26	0	0	0	0	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R31	0	0.14	0	0	0	0	0	0	0	0.31	0.33	0	0.50	0	0	0	0	0	0	0	0	0.33
R32	0	0	0	0	0	0	0.75	0	0	0.14	0	0	0.50	0	0	0	0	0	0	0	0	0
R33	0	0.43	0	1.00	0	0	0	0.50	0	0.31	0	0	0	0.50	0	0	0.50	0.25	0	0	0	0.33
R34	0	0.43	0	0	0	0	0	0.50	0	0.24	0.33	0	0	0.50	0	1.00	0	0.75	0	0	0	0.33
R35	0	0	0	0	0	0	0.25	0	0	0	0.33	0	0	0	0	0	0.50	0	0	0	0	0
R41	0	0	0	0	0	0	0	0	0	0	0	0	0.75	0	0	0	0	0	0	0	0	0
R42	0	0	0	0	0	0	0.25	0.83	1.00	0.33	0	0	0	0	0.83	0	0	0	0.50	0	0	0.25
R43	0	0	0	0	0	1.00	0.75	0	0	0.33	0	0	0	0	0	0	0	0	0	1.00	0	0.75
R44	0	0	0	0	0	0	0	0.17	0	0.33	1.00	0	0.25	0	0.17	0	0	0	0.50	0	0	0

Table S11 The Weighted super matrix

	R11	R12	R13	R14	R15	R16	R17	R21	R22	R23	R24	R25	R26	R31	R32	R33	R34	R35	R41	R42	R43	R44
R11	0	0	1.00	0.49	0	0	0.21	0	0	0	0.20	0.58	0	0	0.72	0	0	0	0.67	0	0	0.28
R12	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R13	0.19	0.25	0	0	1.00	0.51	0.05	0	0.45	0	0	0	0	0	0	0	0	0	0	0	1.00	0
R14	0.19	0	0	0	0	0.17	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.28
R15	0	0	0	0	0	0	0	0	0	0.56	0.20	0	0	0	0	0.76	0.76	0	0	0	0	0
R16	0	0.25	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R17	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R21	0.42	0	0	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.60	0	0
R23	0	0.36	0	0	0	0	0	0	0.33	0	0.15	0	0.24	0	0	0	0	0	0	0	0	0
R24	0	0	0	0	0	0	0	0	0	0	0	0.42	0.24	0	0	0	0	0	0	0	0	0
R25	0	0	0	0	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0	0.01	0	0	0
R26	0	0	0	0	0	0	0.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R31	0	0.02	0	0	0	0	0	0	0	0.05	0.04	0	0.10	0	0	0	0	0	0	0	0	0.06
R32	0	0	0	0	0	0	0.09	0	0	0.02	0	0	0.10	0	0	0	0	0	0	0	0	0
R33	0	0.06	0	0.15	0	0	0	0.19	0	0.05	0	0	0	0.50	0	0	0.12	0.25	0	0	0	0.06
R34	0	0.06	0	0	0	0	0	0.19	0	0.04	0.04	0	0	0.50	0	0.24	0	0.75	0	0	0	0.06
R35	0	0	0	0	0	0	0.03	0	0	0	0.04	0	0	0	0	0	0.12	0	0	0	0	0
R41	0	0	0	0	0	0	0	0	0	0	0	0	0.24	0	0	0	0	0	0	0	0	0
R42	0	0	0	0	0	0	0.05	0.51	0.22	0.09	0	0	0	0	0.24	0	0	0	0.16	0	0	0.07
R43	0	0	0	0	0	0.33	0.14	0	0	0.09	0	0	0	0	0	0	0	0	0	0.40	0	0.20
R44	0	0	0	0	0	0	0	0.10	0	0.09	0.19	0	0.08	0	0.05	0	0	0	0.16	0	0	0

Table S12 The Limiting super matrix

	R11	R12	R13	R14	R15	R16	R17	R21	R22	R23	R24	R25	R26	R31	R32	R33	R34	R35	R41	R42	R43	R44
R11	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226	0.226
R12	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
R13	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181
R14	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
R15	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071
R16	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
R17	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044

R21	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113
R22	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
R23	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
R24	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
R25	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
R26	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
R31	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
R32	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
R33	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
R34	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
R35	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
R41	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
R42	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
R43	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
R44	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016

Table S13 Expert rating results

	1	2	3	4	5	6	7	8	9	10
R11	0.7	0.6	0.6	0.4	0.6	0.5	0.4	0.6	0.5	0.7
R12	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.3	0.1
R13	0.6	0.7	0.5	0.5	0.6	0.5	0.4	0.5	0.6	0.7
R14	0.3	0.4	0.2	0.3	0.5	0.4	0.3	0.4	0.5	0.3
R15	0.5	0.5	0.4	0.6	0.3	0.4	0.4	0.6	0.4	0.3
R16	0.1	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.2	0.1
R17	0.4	0.3	0.2	0.3	0.2	0.5	0.3	0.3	0.3	0.4
R21	0.5	0.6	0.4	0.5	0.5	0.4	0.6	0.5	0.5	0.4
R22	0.4	0.3	0.3	0.2	0.2	0.3	0.5	0.3	0.4	0.3
R23	0.2	0.1	0.3	0.1	0.3	0.1	0.4	0.2	0.1	0.3
R24	0.1	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.2	0.1
R25	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1
R26	0.2	0.2	0.1	0.1	0.2	0.4	0.1	0.2	0.1	0.3
R31	0.1	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.2	0.1
R32	0.1	0.2	0.2	0.1	0.3	0.3	0.1	0.2	0.1	0.2
R33	0.4	0.2	0.3	0.5	0.2	0.2	0.2	0.3	0.3	0.2
R34	0.3	0.2	0.4	0.5	0.2	0.2	0.2	0.3	0.3	0.2
R35	0.2	0.1	0.1	0.1	0.3	0.3	0.1	0.2	0.1	0.2
R41	0.1	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.2	0.1
R42	0.5	0.4	0.5	0.6	0.5	0.3	0.6	0.4	0.4	0.3
R43	0.3	0.4	0.5	0.1	0.3	0.2	0.3	0.3	0.1	0.3
R44	0.2	0.3	0.1	0.1	0.2	0.4	0.1	0.1	0.2	0.3

Table S14 The table of Grey evaluation coefficients

Level 1 Indicators	Level 2 Indicators	Evaluation coefficients for gray clustering of the kth gray class					Composite gray evaluation coefficient
		k=1	k=2	k=3	k=4	k=5	
R1	R11	0	2	8	8	6.22	24.22
	R12	5	5.33	3.2	2.286	1.778	17.594
	R13	0	2	8.2	8	6.222	24.422
	R14	0	7.33	7.2	5.143	4	23.673
	R15	0	5.33	8	5.714	4.44	23.484
	R16	5	5.33	3.2	2.286	1.78	17.596
	R17	0	8	6.4	4.57	3.55	22.52
R2	R21	0	3.667	9	7	5.44	25.107
	R22	0	8	6.4	4.57	3.55	22.52
	R23	4	6.33	4.2	3	2.33	19.86
	R24	5	5.33	3.2	2.286	1.778	17.594
	R25	6	4.667	2.8	2	1.556	17.023
	R26	4	5.667	3.8	2.71	2.11	18.287
R3	R31	5	5.33	3.2	2.286	1.778	17.594
	R32	4	6	3.6	2.57	2	18.17
	R33	0	7.33	5.6	4	3.11	20.04
	R34	0	7.33	5.6	4	3.11	20.04
	R35	5	5.667	3.4	2.43	1.889	18.386
R4	R41	5	5.33	3.2	2.286	1.778	17.594
	R42	0	5	8.2	6.429	5	24.629
	R43	2	7.33	5.6	4	3.11	22.04
	R44	4	6	4	2.857	2.22	19.077

Supplementary Materials S15

BIPV Residential Project Development Risk Identification Questionnaire

Respected experts:

Greetings! Your support for this research is greatly appreciated. The purpose of this questionnaire is to evaluate the WBS-RBS risk identification coupling matrix that has been developed in this paper for the entire life cycle of BIPV residential project development. The first line indicates the manner in which the project’s work elements are partitioned into phases, comprising 16 items in total. The 27 items comprising the elements of

risk classified by the risk decomposition structure are displayed in the first column. When identifying risks, please assign a numerical value between 0 and 1 to each identified risk and determine whether or not the corresponding risk point exists. A value of "1" suggests the occurrence or likelihood of a similar risk, whereas a value of "0" signifies the absence of or its negligible probability of emerging. Kindly complete the form in an unbiased and fair manner. Sincerely, best of luck with your work, thanks!

WBS-RBS Risk Coupling Matrix for BIPV Residential Project Development

Risk factors	Market research	Feasibility studies	Financing preparation	Project Filing	Development project approval	Bidding for design units	Project design	Load forecasting
Project finance r								
Incremental cost								
Electricity billing								
Feed-in tariff								
Tendering methods and contractor qualifications								
Security management								
Progress management								
Contract management								
Cost management								
Inadequate design codes and standards								
Incomplete policies and regulations								
Inadequate acceptance criteria								
Impact of force majeure factors								
BIPV Market supply								
Load forecasting								
Consumer acceptability								
Project Programming								
Masterplan design								
Project Location								
Grid connection								
Project integrated design								
Maintenance technology for photovoltaic equipment								
	Grid-connected declarations	Project bidding	Completion stage	Construction phase	Construction preparation phase	Grid connection acceptance application	Equipment commissioning	Detecting operational status
Project finance								
Incremental cost								
Electricity billing								
Feed-in tariff risk								
Tendering methods and contractor qualifications								

Security management								
Progress management								
Contract management								
Cost management								
Inadequate design codes and standards								
Incomplete policies and regulations								
Inadequate acceptance criteria								
Impact of force majeure factors								
BIPV Market supply								
Load forecasting								
Consumer acceptability								
Project Programming								
Masterplan design								
Project Location								
Grid connection								
Project integrated design								
Maintenance technology for photovoltaic equipment								
Project finance								
Incremental cost								
Electricity billing								
Feed-in tariff								
Tendering methods and contractor qualifications								
Security management								
Progress management								
Contract management								
Cost management								
Inadequate design codes and standards								

Supplementary Materials S16

BIPV Residential Development Risk Factors Expert Interview Questionnaire

Dear Ms./Mr.:

Greetings! To begin with, I would like to extend my sincere appreciation for your time in managing your busy schedule to participate in this survey!

As a master’s candidate Nanjing Forestry University, I am working on my dissertation titled "An investigation into the Risk Assessment of BIPV Residential Project Development Utilizing the DEMATEL-ANP Methodology— — Take a project in China as an example". The objective of this questionnaire was to investigate "the importance of risk factors in BIPV residential development".

Following an extensive review of relevant literature and data analysis, this paper screens 22 risk factors associated with BIPV residential development. To enhance the validity and efficacy of the evaluation index, kindly assess the significance of the 22 influencing factors based on your understanding and practical experience in PV building integration.

Here we express our gratitude for your cooperation!
Best of luck with your professional endeavor and happiness!

Nanjing Forestry University
July 2023

Part 1: Your Basic Information

- 1 Your Occupation:
 A an academic instructor B a Practitioner in Construction C a Photovoltaic Practitioner D Government employee E Others
- 2 To what extent do you understand policies related to the construction sector in the context of carbon neutrality:
 A have never heard of it B am very ignorant of it C am only marginally knowledgeable D am extremely knowledgeable
- 3 What would be your perception of the transformation of the construction industry in a carbon-neutral situation:
 A Passive House Construction B Assembly Building C Green Building D Photovoltaic and Building Integration E Others
- 4 Have you encountered anything in your life concerning photovoltaics or photovoltaic building integration?
 A Undoubtedly not B Negligible C Fairly well D Very well
- 5 What is your perspective regarding the integration of photovoltaic systems into residential buildings?
 A Dangerous B unknown C Energy-conserving
- 6 Consider yourself within a residence that has been integrated with photovoltaic technology, , your inner thoughts are:
 A green B advanced and intelligent C hazardous D prone to accidents
- 7 Would you be interested in purchasing electricity generated by the combination of photovoltaics and buildings for residential and industrial use?
 A extremely reluctant B moderately willing C somewhat willing D extremely willing
- 8 Should the degree of PV integration with building design and construction be firmly established, would you consider making a purchase of it?
 A extremely reluctant B moderately willing C somewhat willing D extremely willing

Part 2: This section examines the significance of 22 risk factors affecting BIPV residential development. Kindly assess the significance of the influencing factors regarding the current state of the development of BIPV residential projects in China and your own professional and social background, and indicate with a checkmark in the corresponding table. (Evaluations were determined using a 5-point Likert scale, where 1-irrelevant, 2-unimportant, 3-average, 4-important, and 5-extremely important.)

BIPV Residential Development Risk Factor Questionnaire

Serial number	Risk factors	Degree of impact				
		1	2	3	4	5
1	Consumer acceptance					
2	BIPV Market Supply					
3	Project finance					
4	Project location					
5	Incremental cost					
6	Feed-in tariff					
7	Changes in policies and regulations					
8	Master Plan Design					
9	Load forecasting					
10	Poor program design					
11	Project Integration and Design					
12	Tendering methods and contractor qualification					
13	Inadequate design codes and standards					
14	Security management					
15	Inadequate criteria for quality acceptance					
16	Cost management					
17	Progress management					
18	Contract management					
19	Technical risk of PV equipment maintenance					
20	Grid connection					
21	Force majeure					
22	Cost management					

Supplementary Materials S17

Questionnaire for two-by-two comparison of the degree of dominance of risk indicators for risk assessment of BIPV residential projects
Dear Ms./Mr.

We express our gratitude for your attention to this survey. This questionnaire is an extension of the second questionnaire , which aimed to obtain the interactions between risk indicators in order to generate a two-by-two dominance comparison matrix. I hope that you will utilize this questionnaire to provide feedback regarding the dominance of the first and second levels of risk indicators. The references between the risk indicators are detailed in the table below:

References between risk indicators for BIPV residential project development	
Standardized layer	Indicator layer
Pre-decision phase exposures R1	Risk of inadequate policies and regulations (R11) BIPV market supply risk(R12) Project finance risks(R13) Site selection risks (R14) Risk of consumer acceptance(R15) Feed-in tariff risk(R16) Incremental cost risk(R17)
Preparation and design phase exposures R2	Risk of poor project master planning(R21) Risk of load forecasting accuracy(R22) Risk of poor project program design(R23) Risks to the level of integrated project design(R24) Tendering methods and contractor qualification risks(R25) Risk of not improving design codes, standards and related atlases(R26)
Project implementation phase exposures R3	Construction safety risks(R31) Risk of inadequate criteria for quality acceptance (R32) Risks in construction cost management(R33) Risks of construction schedule management(R34) Construction contract management risks(R35)
Operation and maintenance phase exposures R4	Risk of not having well-established technical standards for PV equipment maintenance(R41) Grid acceptance and commissioning risks(R42) Risk of regular billing for electricity(R43) Risk of inoperability due to natural disasters(R44)

This survey utilized a 1-9 scale to assign scores, where positive and negative values indicated degrees of dominance . This survey was conducted using the Super decision software, as illustrated below.

1. Choose

Node Cluster

Choose Node

R17

Cluster: R1

Choose Cluster

R1

2. Node comparisons with respect to R17

Graphical Verbal Matrix Questionnaire Direct

Comparisons wrt "R17" node in "R1" cluster

R11 is moderately more important than R12

1. R11

>=9.5

9

8

7

6

5

4

3

2

1

2

3

4

5

6

7

8

9

>=9.5

No comp.

R12

2. R11

>=9.5

9

8

7

6

5

4

3

2

1

2

3

4

5

6

7

8

9

>=9.5

No comp.

R13

3. R11

>=9.5

9

8

7

6

5

4

3

2

1

2

3

4

5

6

7

8

9

>=9.5

No comp.

R14

4. R11

>=9.5

9

8

7

6

5

4

3

2

1

2

3

4

5

6

7

8

9

>=9.5

No comp.

R16

5. R12

>=9.5

9

8

7

6

5

4

3

2

1

2

3

4

5

6

7

8

9

>=9.5

No comp.

R13

6. R12

>=9.5

9

8

7

6

5

4

3

2

1

2

3

4

5

6

7

8

9

>=9.5

No comp.

R14

7. R12

>=9.5

9

8

7

6

5

4

3

2

1

2

3

4

5

6

7

8

9

>=9.5

No comp.

R16

8. R13

>=9.5

9

8

7

6

5

4

3

2

1

2

3

4

5

6

7

8

9

>=9.5

No comp.

R14

9. R13

>=9.5

9

8

7

6

5

4

3

2

1

2

3

4

5

6

7

8

9

>=9.5

No comp.

R16

10. R14

>=9.5

9

8

7

6

5

4

3

2

1

2

3

4

5

6

7

8

9

>=9.5

No comp.

R16

Supplementary Materials S18

Respected experts:

Greetings! Your support in this research is greatly appreciated. The purpose of this questionnaire is to assess the risk level. This study classifies the risk associated with the development of BIPV residential project into five distinct levels: "extremely low", "low", "medium", "high", and "extremely high" . These levels are determined by the probability of occurrence, severity of loss, and controllability of the risk, in that order from low to high. The range of values for risk measurement is represented by the number of intervals [0,1], and the set of rubrics and evaluation criteria are illustrated in the table.

Kindly assign an objective and fair score to the risk level referenced in the table provided. Your participation in this survey is highly appreciated, and I extend my best wishes for your continued happiness!

Evaluation criterion.		
Risk level	Scope of risk measurement	Evaluation criteria
low	[0,0.2]	This risk has an exceedingly low probability of occurrence and exerts a nearly negligible impact on the project when it occurs.
relatively low	(0.2,0.4)	This risk has a low probability of occurrence, and exerts a low impact and loss on the project when it occurs, and does not impede the accomplishment of the project objectives.
moderate	(0.4,0.6]	This risk has a moderate probability of occurrence and may cause a moderate amount of damage and financial loss to the project when it occurs, but measures can be taken to restore normalcy.
high	(0.6,0.8]	This risk has a high probability of occurrence, it could result in significant loss and damage to the project when it occurs.
extremely high	(0.8,1]	This risk has a high probability of occurrence. Its occurrence can have serious impacts and result in substantial repercussions for the project, ultimately impeding the achievement of its goals.

Risk Level Scoring Scale

Standardized layer	Indicator layer	Scoring
Pre-decision phase exposures R1	Risk of inadequate policies and regulations (R11)	
	BIPV market supply risk(R12)	
	Project finance risks(R13)	
	Site selection risks (R14)	
	Risk of consumer acceptance(R15)	
	Feed-in tariff risk(R16)	
	Incremental cost risk(R17)	
Preparation and design phase exposures R2	Risk of poor project master planning(R21)	
	Risk of load forecasting accuracy(R22)	
	Risk of poor project program design(R23)	
	Risks to the level of integrated project design(R24)	
	Tendering methods and contractor qualification risks(R25)	
	Risk of not improving design codes, standards and related atlases(R26)	
Project implementation phase exposures R3	Construction safety risks(R31)	
	Risk of inadequate criteria for quality acceptance (R32)	
	Risks in construction cost management(R33)	
	Risks of construction schedule management(R34)	
	Construction contract management risks(R35)	
Operation and maintenance phase exposures R4	Risk of not having well-established technical standards for PV equipment maintenance(R41)	
	Grid acceptance and commissioning risks(R42)	
	Risk of regular billing for electricity(R43)	
	Risk of inoperability due to natural disasters(R44)	