Supplementary Information (SI) for Energy & Environmental Science.

Electronic supplementary information

An Ultra-High Output Self-Managed Power System Based on a Multilayer Magnetic Suspension Hybrid Nanogenerator for Harvesting Water Wave Energy

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Supplementary Movies:

Supplementary Movie 1. The bulb array is illuminated by the ESPS.

Supplementary Movie 2. A water quality tester is powered by the ESPS to transmit wireless signal to a mobile phone.

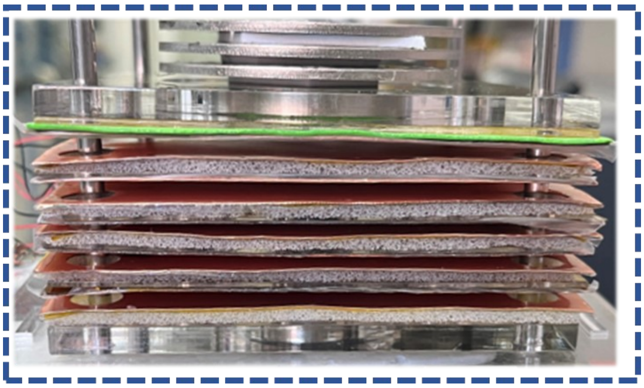

Figure S1. The photograph of the MS-HNG.

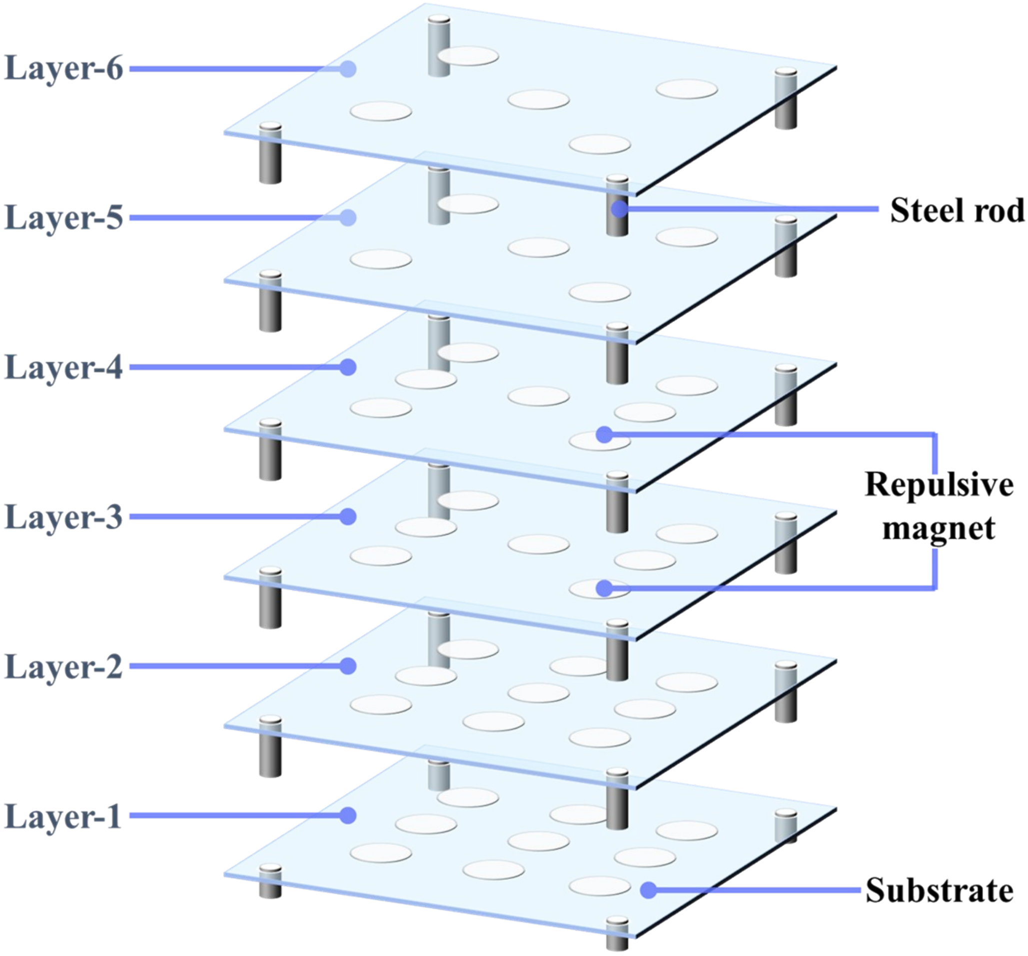

Figure S2. Detailed view of the magnets embedded in each substrate layer.

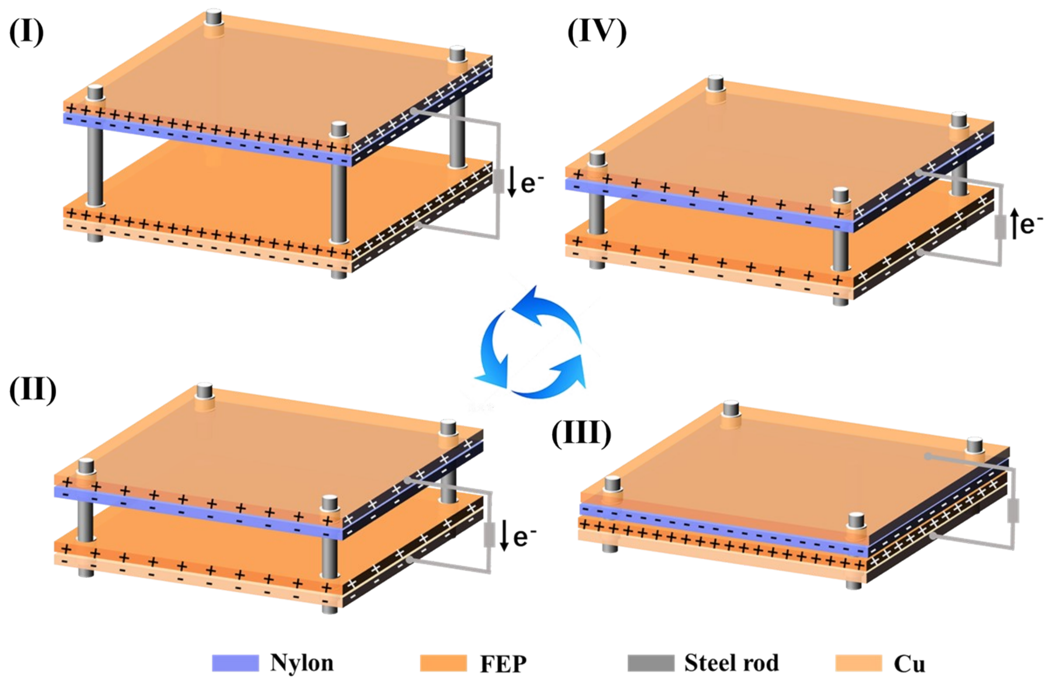

Figure S3. Working principle of the proposed MS-TENG.

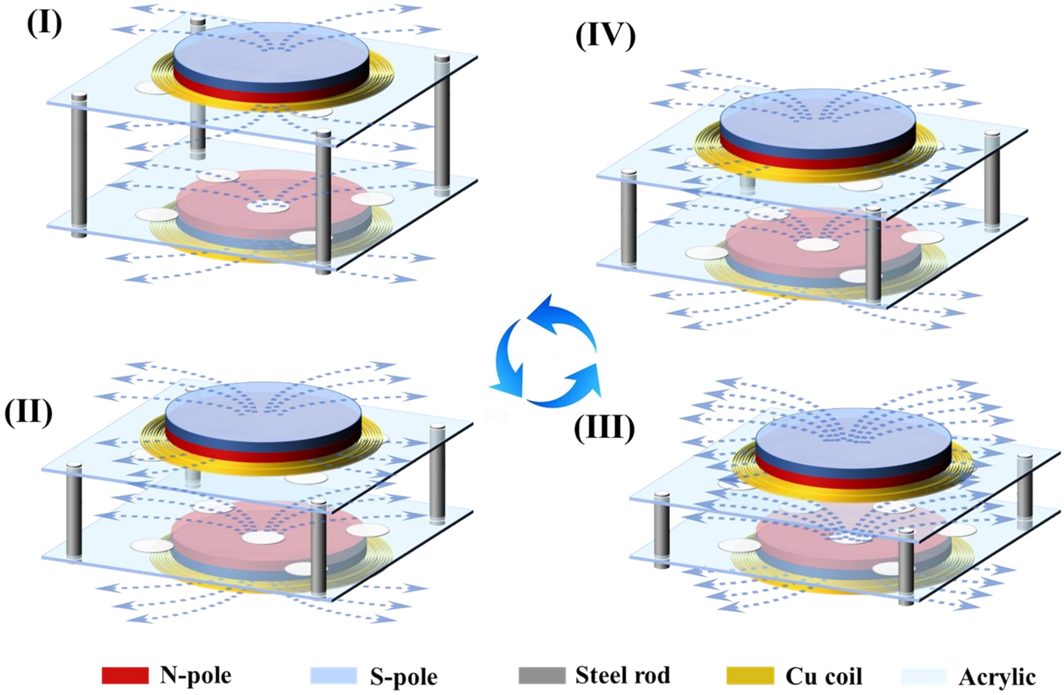

Figure S4. Working principle of the proposed MS-EMG.

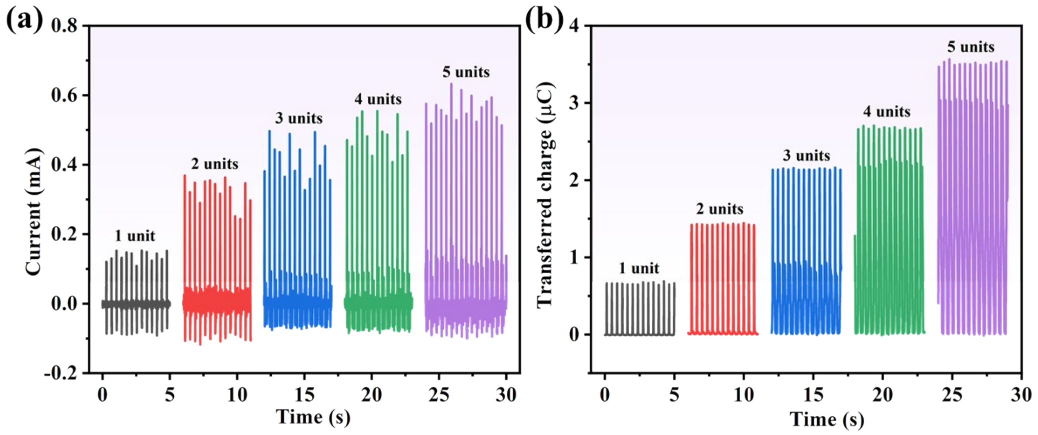

Figure S5. Effect of the number of generating units on (a) short-circuit current and (b) transferred charge of the MS-TENG.

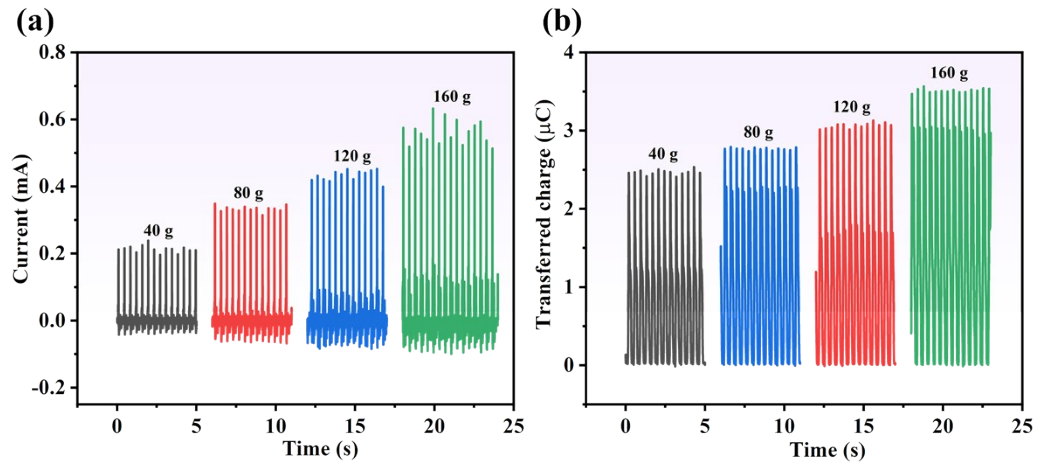

Figure S6. Effect of the counterweight mass on (a) short-circuit current and (b) transferred charge of the MS-TENG.

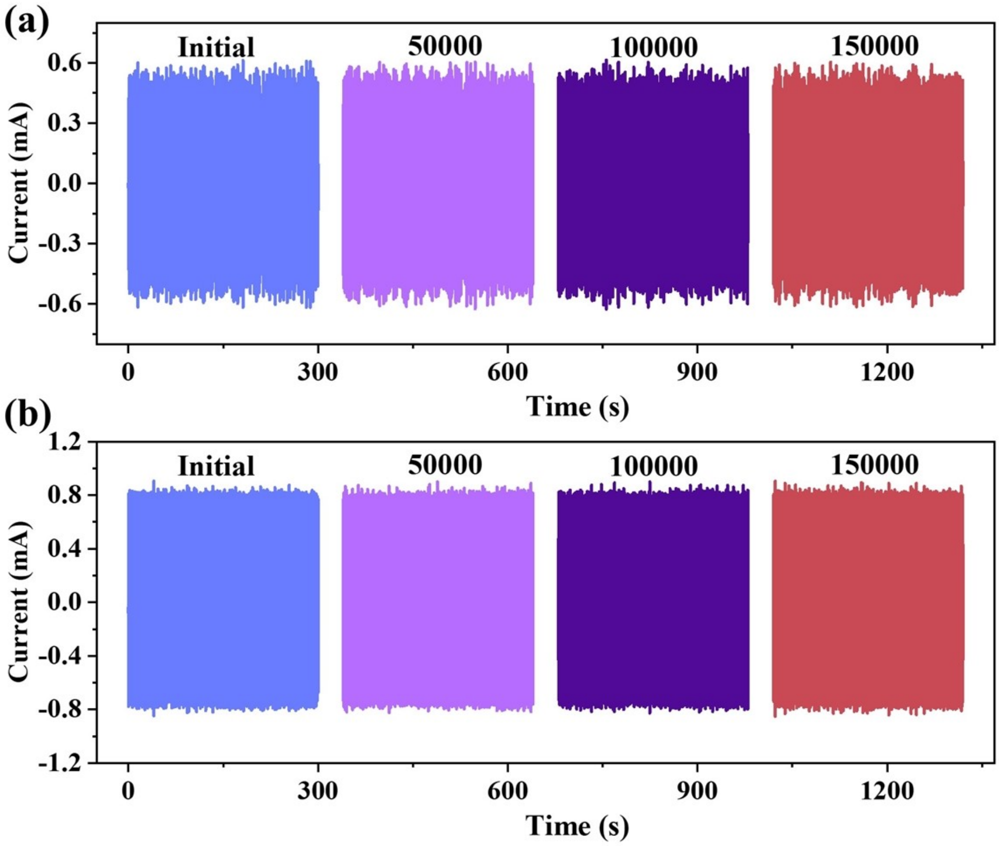

Figure S7. Durability result for the current of the (a) MS-TENG and (b) MS-EMG at various cycles.

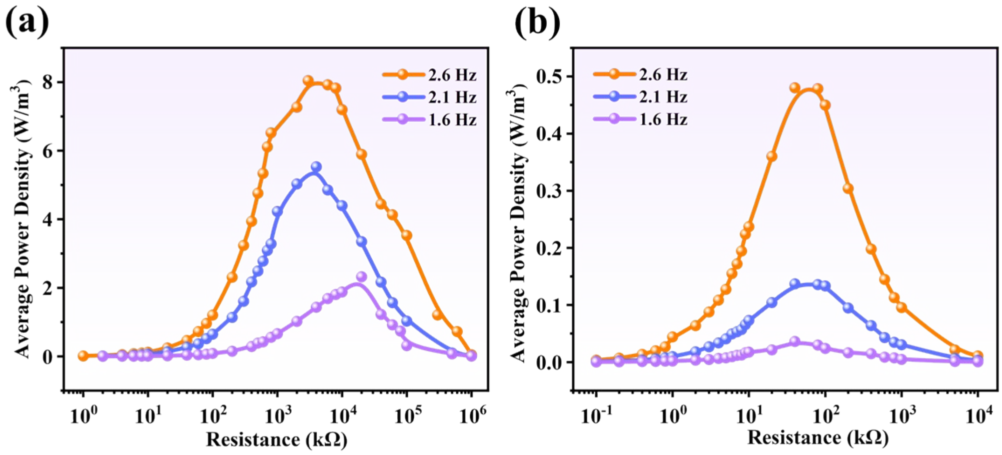

Figure S8. The average power density of the (a) MS-TENG and (b) MS-EMG at different frequencies.

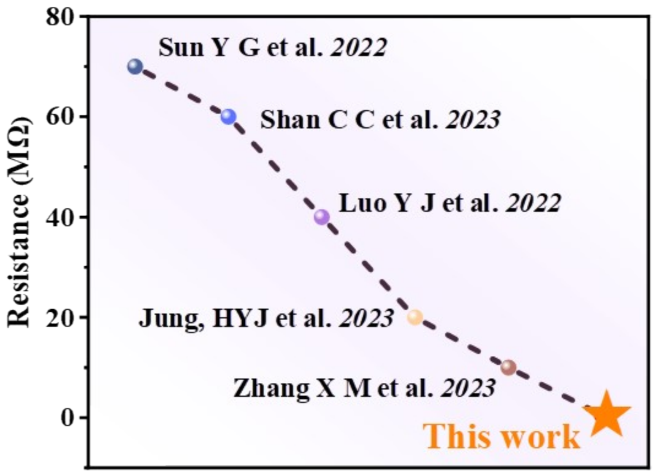

Figure S9. Comparison of the impedance between the MS-TENG and other excellent TENGs.[1-5]

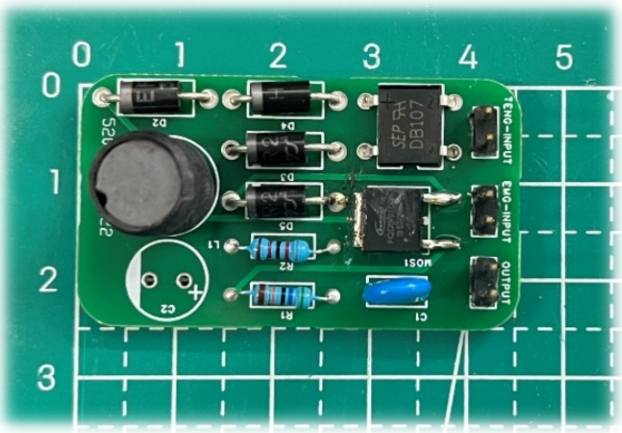

Figure S10. The photograph of the PCB board.

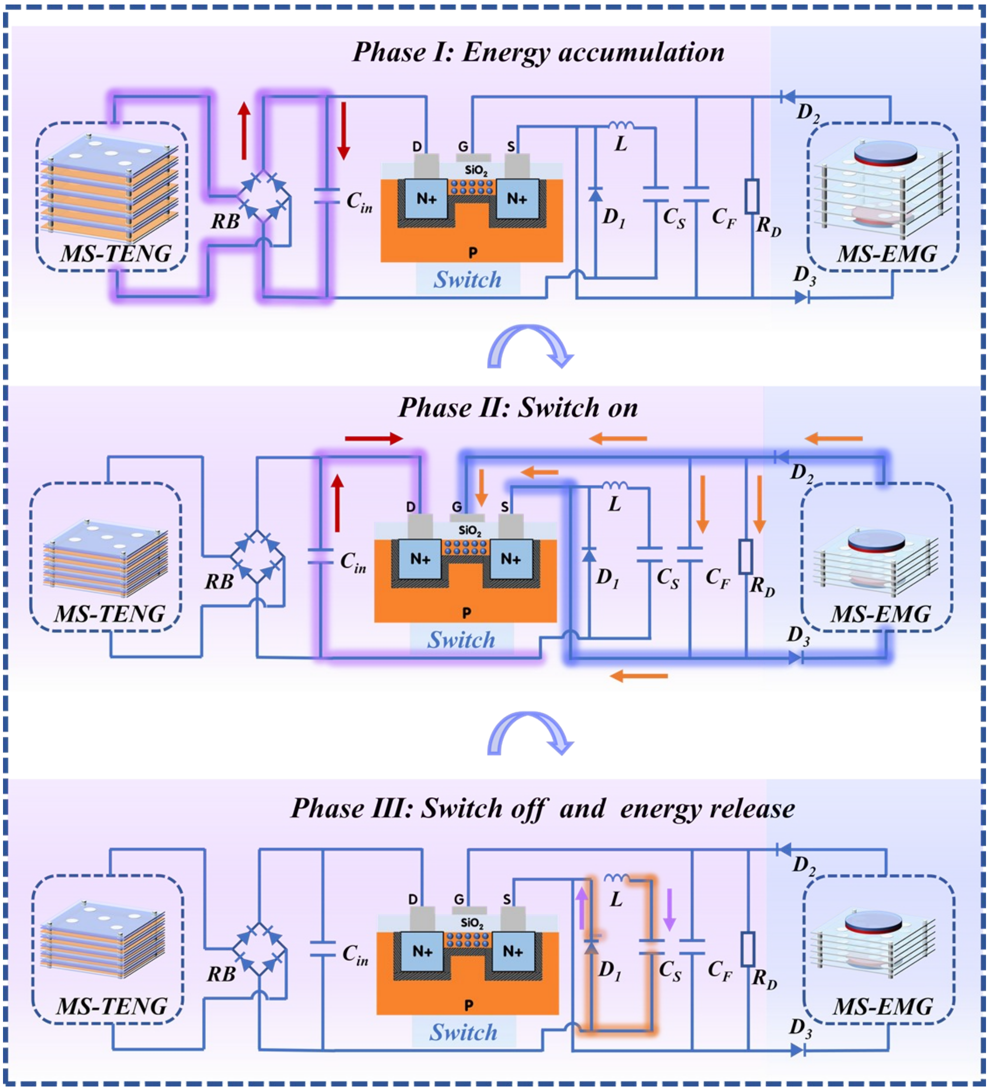

Figure S11. Working process of the ESPS.

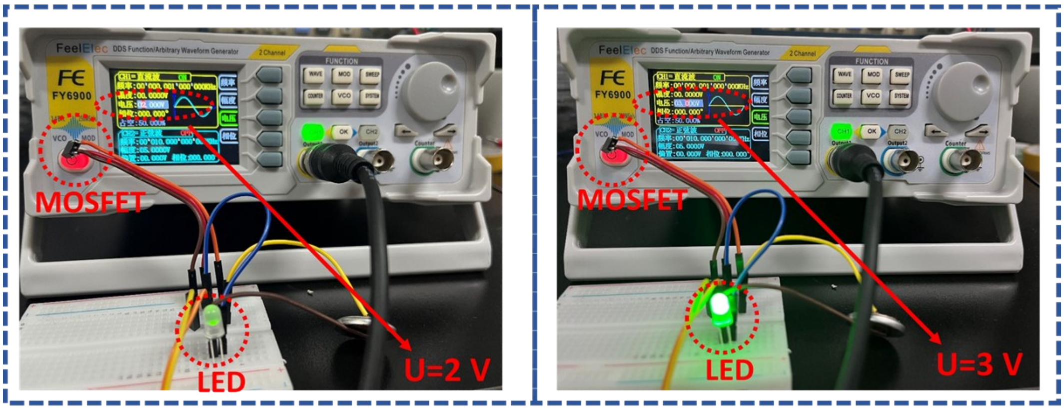

Figure S12. Verification of MOSFET turn-on voltage varies according to LED signals.

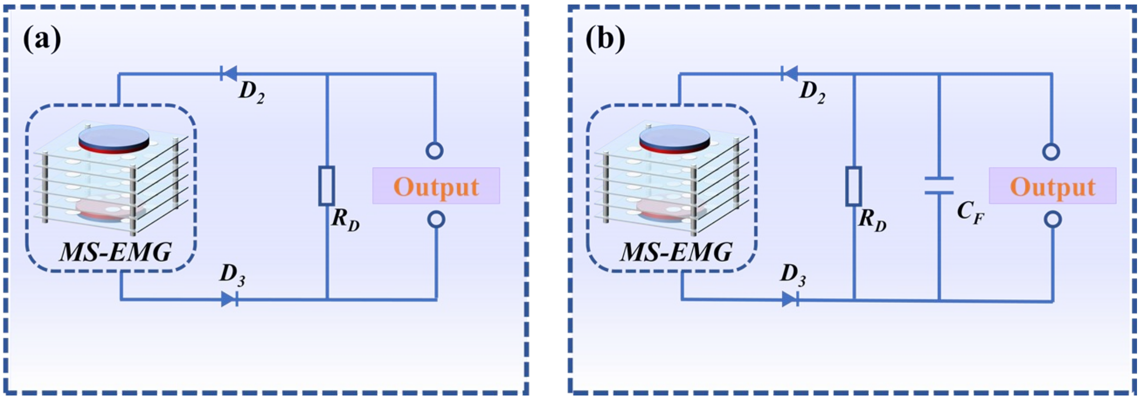

Figure S13. Circuit connections with exploration of resistance and capacitance parameters.

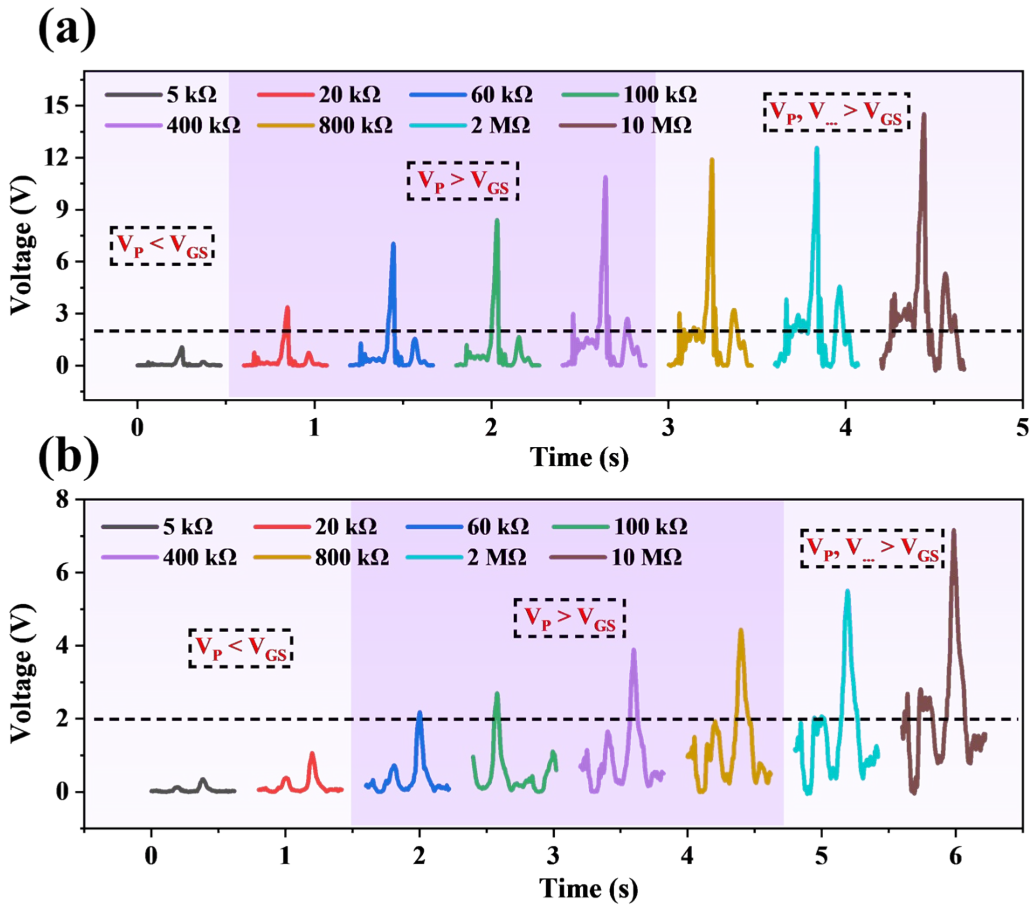

Figure S14. Effect of voltage divider resistor (R_D) on the output voltage of the MS-EMG at (a) 2.1Hz and (b) 1.6 Hz, respectively.

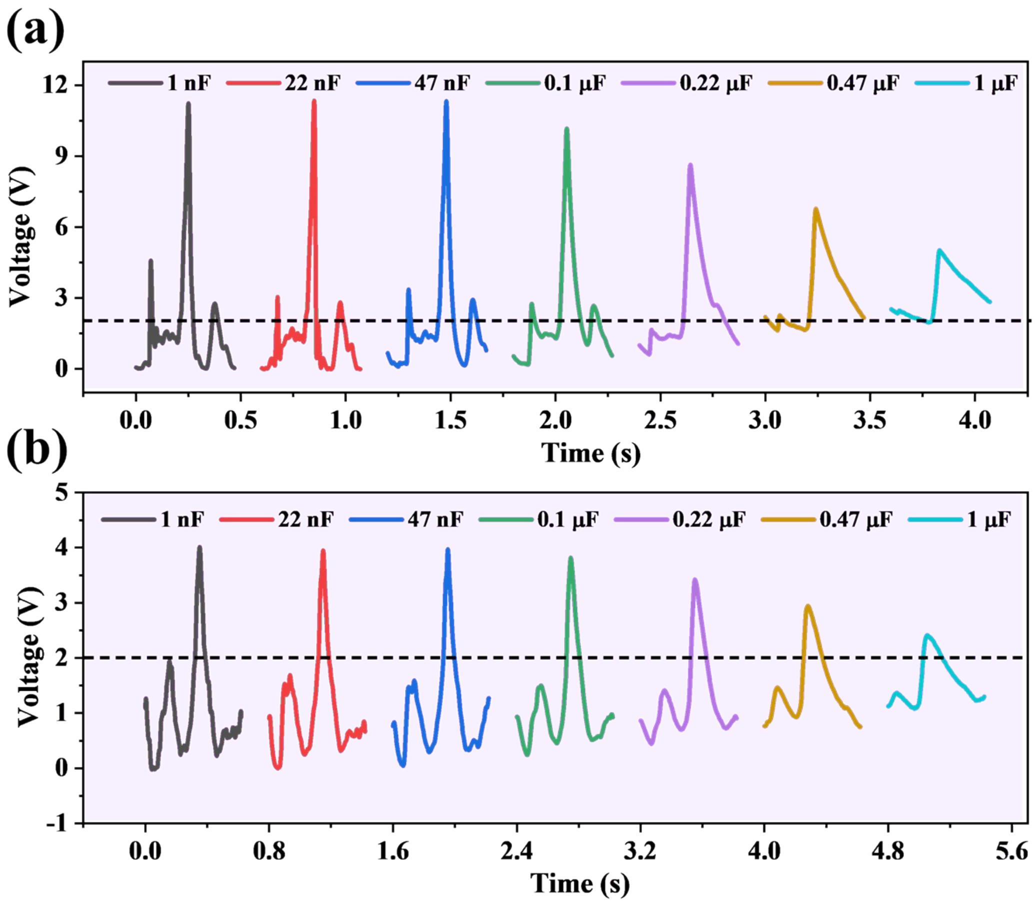

Figure S15. Effect of filter capacitor (C_F) on the output voltage of the MS-EMG at (a) 2.1Hz and (b) 1.6 Hz, respectively.

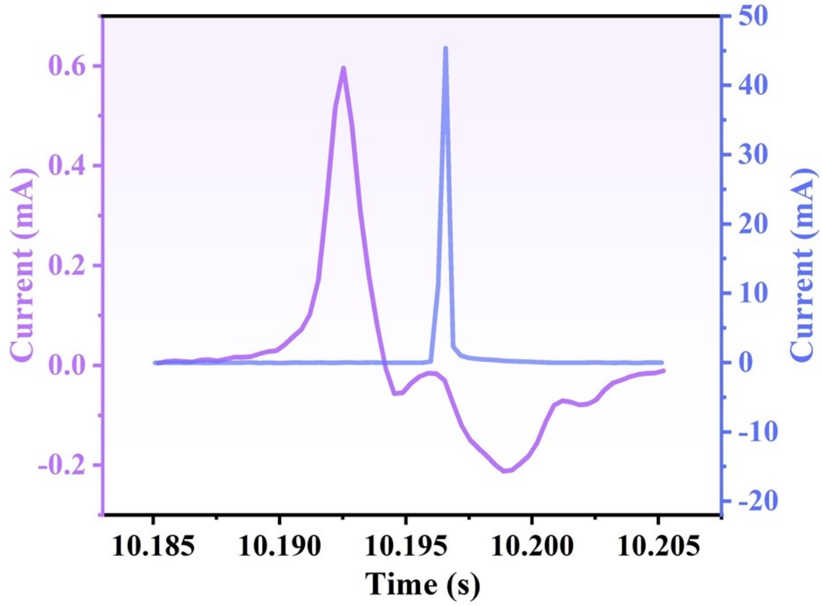

Figure S16. Comparison of alternating current and direct current of ESPS.

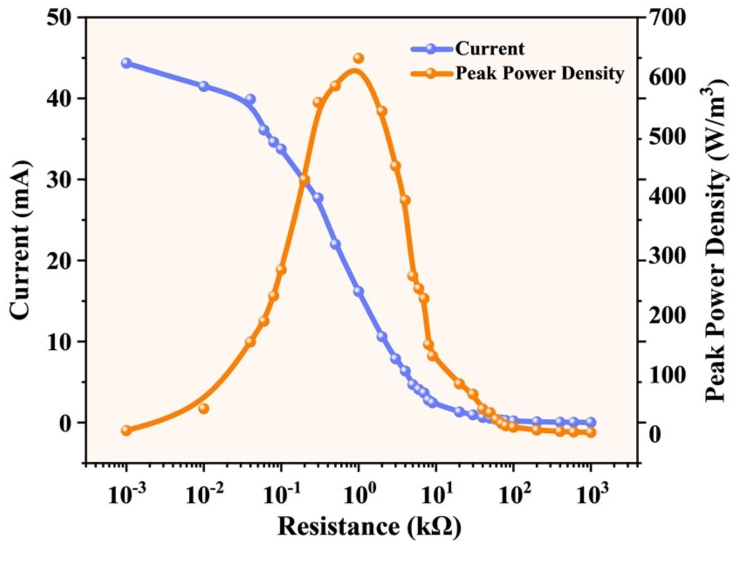

Figure S17. The current and peak power density with respect to the load resistance for the ESPS.

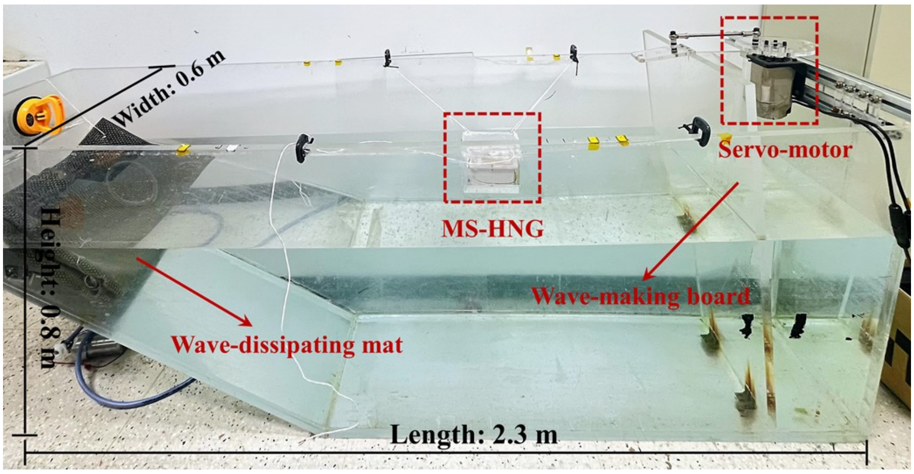

Figure S18. The photograph of wave-making apparatus.

Table S1. Comparison of device shape, mechanism, excitation condition, power and energy management for different types of triboelectric-electromagnetic hybrid nanogenerators.

Device Shape	Hybrid Module	Mechanism	Excitation	Power / Power Density	Power Ratio	Energy Management	Ref
Bidirectional Rotating Turbine	TENG	Freestanding	1 Hz	115 mW	1:10	No	6
	EMG	Transverse cutting		350 mW		No	
Box	TENG	Rolling	1.8 Hz	0.08 mW	1:186	NO	7
	EMG	Transverse cutting		14.9 mW		No	
Paper-based zigzag multilayer	TENG	Contact-separation	1 Hz	22.5 mW	16:1	No	8
	EMG	Transverse cutting		1.39 mW		No	
Topological Structure	TENG	Contact-separation	1 Hz	0.5 mW	1：8	NO	9
	EMG	Longitudinal cutting		4 mW		NO	
Cylinder	TENG	Freestanding	0.2 Hz	13.77 W/m^3	1:11	NO	10
	EMG	Transverse cutting		148.24 W/m^3		NO	
Clip-like structure	TENG	Contact-separation	2.6 Hz	16 mW	100:1	Yes	11
	EMG	Longitudinal cutting		0.16 mW		Yes	
Magnetic-Levitation	TENG	Contact-separation	8 m s^{-2}	12.17 mW	26:1	Yes	12
	EMG	Longitudinal cutting		0.47 mW		NO	
Chaotic pendulum	TENG	Freestanding	2.5 Hz	15.21 mW	1:82	NO	13
	EMG	Transverse cutting		1.23 mW		NO	
Flexible pendulum structure	TENG	Contact-separation	2.2 Hz	470 mW	1:1113	NO	14
	EMG	Transverse cutting		523 mW		NO	
Double-sided fluff	TENG	Freestanding	1.4 Hz	2.02 W/m^3	1:8	NO	15
	EMG	Transverse cutting		16.96 W/m^3		NO	
Multilayer magnetic suspension	TENG	Contact-separation	2.6 Hz	631 W/m^3	Integrated system	YES	**This work**
	EMG	Longitudinal cutting					

Table S2. Comparison of electrical output of multi-layer TENGs under motor and water waves.

Device structure	Motor Condition			Water Environment			Ref
	Motor Excitation	Matching Impedance	Peak Power /Power Density	Water Frequency	Water Amplitude	Peak Power /Power Density	
Cube	2 Hz	500 MΩ	52.87 W/m³	0.8 Hz	6 cm	80.29 W/m³	16
Open-book	1 Hz	13.8 MΩ	9.675 W/m³	0.588 Hz	/	7.45 W/m³	17
Pendulum	1Hz	200MΩ	15.15 W/m³	0.3 Hz	/	14.71 W/m³	18
Disk	1Hz	1MΩ	29.4mW	0.58Hz	/	45.0mW	19
swing	1 Hz	/	12.1 mW	1 Hz	10 cm	4.1 mW	20
pendulum	20°	1 MΩ	39.2 mW	/	/	3.1 mW	21
Spherical	2.5 Hz	/	5.5 mW	1.0 Hz	9 cm	2.5 mW	22
swing	2 Hz	/	53.5 mW	0.8 Hz	7.0 cm	27.6 mW	23
Anaconda	20°	5 MΩ	347 W/m³	/	/	80.61 W/m³	24
Pendulum	20°	5 MΩ	200 W/m³	/	/	34.7 W/m³	25
Magnetic suspension	2.6 Hz	1 kΩ	631 W/m³ (261.3 mW)	1 Hz	10 cm	120 W/m³ (49.7mW)	**This work**

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