



TALOS



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POLICY BRIEF

Autonomous Robotics for Solar PV Maintenance

Removing Barriers to Scale

Table of Content

Introduction & Key Messages	4
The Challenge: Why Regulation is the Bottleneck	5
Land-Based-PV: Industrial-Scale Autonomy Without a Rulebook	6
Agrivoltaics (AgriPV): A Dual-Use Technology Without a Legal Identity	8
Floating PV (FPV): Innovation on Water, Stranded by Red Tape	10
Cross-Cutting Policy Recommendations	12
From Evidence to Action: How TALOS Contributes	14
Key References	15
About TALOS	15



Introduction & Key Messages

Europe's solar PV capacity surpassed 300 GW in 2025 and must reach around 720 GW by 2030 to meet the revised REPowerEU targets.

The human workforce cannot scale maintenance at the same pace. Autonomous robotic systems (drones, unmanned ground vehicles (UGVs) and AI-powered inspection platforms) are technically ready to fill this gap, but are not being deployed at scale. The reason is not technological. It is regulatory.

TALOS, a Horizon Europe project, has demonstrated autonomous robotic Operations & Maintenance (O&M) across three real-world solar PV contexts. Its findings reveal a consistent pattern: fragmented, outdated or absent regulatory frameworks are the primary barrier to cost-effective, safe and sustainable robotic O&M. This brief summarises the barriers identified and puts forward concrete recommendations for EU and national policymakers.

Four key messages from TALOS

1 Europe's solar ambitions demand a new regulatory paradigm for autonomous O&M, technology-neutral, cross-sector and harmonised across member states.

2 Fragmented national rules, undefined liability and missing EU-level definitions (especially for AgriPV and floating PV) are slowing deployment.

3 A dedicated EU framework for Autonomous Systems in Renewable Energy Infrastructure, covering safety, liability, data governance and environmental standards, is urgently needed.

4 TALOS shows autonomous robotics can safely and sustainably maintain PV installations across three demanding contexts. The technology is ready. The policy must follow.

The Challenge: Why Regulation is the Bottleneck

Solar PV is the fastest-growing power source in Europe; capacity more than doubled between 2020 and 2024.

Robotic O&M (UAV inspection, UGV cleaning, AI-based decision support) can reduce maintenance costs by 25–50%, enable 24/7 operations, and dramatically cut workplace accidents. Yet deployment lags. Across diverse national contexts, TALOS confirms the primary barriers to deployment are regulatory and structural, not technical. From fragmented permitting rules to connectivity gaps at remote sites.

- **Fragmentation:** Member states apply different, often contradictory, rules to identical technologies.
- **Regulatory gaps:** AgriPV land-use classification, FPV environmental O&M standards, and liability for autonomous systems are unaddressed by existing law.
- **Outdated frameworks:** Industrial, agricultural and waterway safety rules were designed for human-operated equipment, not autonomous systems.
- **Definitional ambiguity:** No EU-level definitions for agrivoltaics or floating PV — creating legal grey areas for permitting, subsidies and authorisations.

EU instruments already in force, but only partially applicable

AI Act: may classify O&M tools as 'high-risk'.

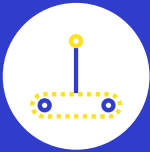
Machinery Regulation 2023/1230: mobile field robots not explicitly addressed.

UAS Regulation: designed for leisure/logistics, not energy O&M.

NIS2 Directive: no provisions specific to autonomous solar systems.

CAP: does not recognise AgriPV/agri-robots in all member states.

Habitats/Birds/Water Framework Directives: no guidance on robotic O&M at FPV sites.



Land-Based-PV Industrial-Scale Autonomy Without a Rulebook

Utility-scale, ground-mounted solar parks are Europe's most mature PV segment, but their O&M rules were designed for human-operated equipment. Autonomous mobile robots (operating unpredictably, at non-standard hours, on grid-critical infrastructure) don't fit existing legal categories.

BARRIERS & RISKS

- Safety classification gap for autonomous mobile systems
- Liability unresolved (manufacturer / integrator / operator)
- Fragmented UAS permits & night-operation limits
- Cybersecurity gaps; no standards for connected systems
- Connectivity gaps (4G/5G) at remote sites
- No certification path for O&M routines or data ownership
- Land-use competition with continued agriculture

OPPORTUNITIES & ENABLERS

- 24/7 autonomous O&M, impossible with human-only teams
- Fewer accidents; lower labour/safety exposure costs
- Supports EU energy independence (REPowerEU)
- New O&M business models; workforce upskilling
- Longer plant lifespan via more precise maintenance
- Co-management models (e.g. sheep grazing) cut land conflict

CHALLENGE	POLICY RECOMMENDATION	TALOS EVIDENCE
No regulatory category for autonomous mobile systems in industrial energy sites; liability for incidents is legally unresolved.	Establish an 'Autonomous Systems in Energy Infrastructure' (ASEI) classification within the Machinery Regulation, plus an EU-level liability regulation defining shared responsibility	TALOS land-based pilot demonstrates multi-modal autonomous O&M (UAV + UGV) operating safely in real solar parks; supports performance-based certification. EU Level • Short-term (2026–2027) DG GROW, DG ENER, CEN/CENELEC
Fragmented UAS permits; no 'energy infrastructure O&M' category; night-operation restrictions block cost-optimal maintenance scheduling.	Create a harmonised 'Energy Infrastructure O&M' UAS category within the EU UAS Regulation, with risk-based night-operation authorisation for enclosed industrial sites.	TALOS has demonstrated night-capable UAV+UGV mission planning under supervised autonomy, providing safety evidence for risk-based authorisation. EU + Member State Level • Short-to-medium-term (2026–2028) EASA, National Aviation Authorities, DG ENER
No cybersecurity standards specifically address autonomous systems connected to solar energy infrastructure; connectivity gaps in remote areas prevent real-time operations.	Mandate cybersecurity requirements for autonomous O&M systems under the NIS2 Directive's implementing acts; include solar park connectivity in EU rural connectivity investment programmes (Digital Decade).	TALOS data architecture provides a reference model for secure, interoperable data flows between autonomous O&M systems and plant management platforms. EU Level • Medium-term (2027–2029) DG CNECT, ENISA, Member State Authorities
No framework certifies autonomous O&M routines or clarifies who owns operational data generated on private solar assets.	Commission a certification pathway for autonomous O&M routines (Machinery Regulation / AI Act) and clarify data ownership/access rights under the EU Data Act.	TALOS has validated standardised O&M mission protocols and a GDPR/Data-Act-aligned data governance model. EU Level • Short-to-medium-term (2026–2028) DG GROW, DG CNECT, National Certification Bodies



Agrivoltaics (AgriPV)

A Dual-Use Technology Without a Legal Identity

AgriPV, co-locating solar energy with active crop agriculture, could generate up to 944 TWh/year across 14 million hectares of suitable EU land while preserving agricultural output. But it has no unified legal identity: is the land agricultural or energy? Is the soil eligible for CAP subsidies?

BARRIERS & RISKS	OPPORTUNITIES & ENABLERS
• No EU legal definition of AgriPV • Land-use status ambiguity (agricultural vs. energy) • UGV regulation gap for AgriPV navigation • Safety risks below/between elevated panels • High upfront costs for small/medium farms • Low tech literacy & social resistance • Limited environmental impact data	• Technology-as-a-Service removes upfront cost barrier • CAP Pillar II funding alignment • Capacity building & farmer-to-farmer learning • Dual productivity: energy + crop yield • Ecosystem services (biodiversity, soil, water) • New rural service jobs & advisory roles

CHALLENGE	POLICY RECOMMENDATION	TALOS EVIDENCE
Regulatory decisions risk being finalised without a systematic, climate-zone-specific evidence base on crop impacts and shading; EIA is not a standard requirement.	Mobilise agricultural extension services for crop-level evidence generation; commission cross-climate shading analysis; make EIA standard for all AgriPV installations.	TALOS AgriPV pilot has operated in a limited number of contexts, underscoring the need for broader, extension-service-led evidence generation before EU-wide rules are set. EU + Member State Level • Short-term (2026–2027) DG AGRI, Extension Services, Research Institutes
Farmer adoption remains slow: too few trusted reference sites, limited structured training, and no dedicated support for early adopters.	Establish multi-climate demonstration sites; fund farmer-to-farmer training programmes; target grants at frontrunner farmers to lower entry barriers.	TALOS social acceptance research shows farmer trust is driven primarily by visible peer outcomes, supporting demonstration- and frontrunner-led diffusion. EU + Member State Level • Short-to-medium-term (2026–2028) DG AGRI, Farmers' Associations, Advisory Networks
No EU-level legal definition of AgriPV creates systemic uncertainty for subsidies, planning and permitting; land-status ambiguity makes AgriPV financially unviable in many states.	Establish a legally operative EU definition of AgriPV (taxonomy, CAP, RED III), classifying it as dual-use land eligible for both CAP and RED III incentives; mandate national licensing frameworks within 24 months.	TALOS AgriPV pilot demonstrates practical dual-use operation, providing an operational base for EU definition development. EU Level (primary) • Short-term (2026–2027) DG AGRI, DG ENER, European Parliament
No EU or national regulation specifically governs UGVs operating in agrivoltaic settings; high upfront costs make AgriPV robotic O&M inaccessible to small and medium farms.	Develop UGV operational standards for AgriPV environments under the Machinery Regulation; create a dedicated AgriPV + Agri-Robotics financial instrument (CAP Pillar II / InvestEU, TaaS leasing) for farms under 50 ha.	TALOS UGV systems validated in AgriPV field environments, providing performance and safety data; TaaS deployment model demonstrates viability for small farms. EU + Member State Level • Short-to-medium-term (2026–2028) DG AGRI, EIB, National Agriculture Ministries
Low tech literacy and social resistance among farming communities limit uptake even where funding is available; no standardised environmental impact data creates EIA uncertainty.	Launch EU-funded capacity-building programmes for farmers, co-designed with farmers' unions; commission an EU-level study on the environmental impacts of AgriPV robotic O&M, leading to standardised EIA guidance.	TALOS social acceptance and human-robot interaction research in the AgriPV pilot informs effective capacity-building and co-design methodologies. EU + Member State Level • Medium-term (2027–2029) DG AGRI, Rural Development Agencies, Research Institutions



Floating PV (FPV)

Innovation on Water, Stranded by Red Tape

Floating PV, panels on lakes, reservoirs and irrigation ponds, could add hundreds of GW of EU capacity while cutting water evaporation by up to 80% and limiting algal growth. But autonomous O&M here spans energy, water-management, conservation and aviation law simultaneously.

BARRIERS & RISKS	OPPORTUNITIES & ENABLERS
• Drone permitting restricted over protected waters • No multi-domain regulatory framework • Technical reliability in humid, wave-exposed conditions • High deployment costs for waterproof systems • Social acceptance deficit; unclear EU Taxonomy status • Dependence on non-EU satellite connectivity • Limited non-harmful wildlife-management tools	• Innovation attraction / living-lab tourism • Multi-use water surfaces (tourism, aquaculture) • Ecological co-benefits: shade, evaporation reduction • Non-harmful bird-deterrent innovation • Emerging business opportunities & EU leadership

CHALLENGE	POLICY RECOMMENDATION	TALOS EVIDENCE
UAS-based O&M over protected water bodies is restricted with no FPV-specific derogation; no multi-domain framework harmonises energy, water and conservation law; reliance on non-EU connectivity providers.	Create an EU-level 'FPV O&M Permit' fast-track category in the UAS Regulation; develop an EU FPV Integrated Regulatory Framework (DG ENER/DG ENV/EASA); invest in EU connectivity infrastructure for remote sites.	TALOS FPV pilot has demonstrated compliant autonomous O&M missions, providing the operational evidence for a fast-track permit category. EU Level • Short-term (2026–2027) EASA, DG ENER, DG ENV
The FPV O&M market is still emerging; high deployment costs and manual-O&M competitiveness slow uptake; social resistance and unclear EU Taxonomy classification constrain financing.	Establish an EU co-investment instrument (InvestEU / Clean Energy Fund) for first-mover deployments; develop social-acceptance toolkits; clarify FPV's EU Taxonomy classification; support a CAPEX-to-OPEX shift via TaaS.	TALOS social research and cost-vs-manual-O&M economic analysis provide an evidence base for the investment case. EU + Member State Level • Short-to-medium-term (2026–2028) DG ENER, EIB, Just Transition Fund
No EU environmental standards address the ecological impacts of autonomous O&M on FPV ecosystems, including wildlife interactions.	Commission an EU FPV Environmental Assessment Standard with guidance on non-harmful wildlife deterrence measures.	INESC CPES has explored non-harmful acoustic bird-deterrent approaches at FPV sites; SLC has designed a dual-purpose deterrent/cleaning sprinkler system — both worth referencing in the EU standard. EU Level • Medium-term (2027–2029) DG ENV, EEA, CEN/CENELEC
FPV autonomous O&M research is fragmented with no coherent EU programme; permit coordination relies on ad-hoc bilateral dialogue with no shared digital platform.	Expand Horizon Europe funding for multi-country FPV O&M demonstrations; develop an open digital platform for FPV permit coordination across member states.	TALOS FPV demonstrations offer a baseline for a research continuation call; TALOS's multi-state permit experience shows the coordination burden a shared platform would resolve. EU Level • Short-to-medium-term (2026–2028) DG RTD, EASA, DG ENER

Cross-Cutting Policy Recommendations

Beyond scenario-specific findings, five systemic policy gaps affect all three PV contexts and require EU-level action, piecemeal national responses will simply perpetuate fragmentation.

1 REGULATE SMARTER: A Coherent Eu Framework For Autonomous Systems In Energy

Challenge: The AI Act, Machinery Regulation, UAS Regulation and NIS2 all partially apply, none provides a unified framework, creating legal uncertainty and high compliance burden for SMEs.

Key actions: Issue interpretive guidance on Autonomous Systems in Renewable Energy Infrastructure (ASREI); develop targeted Delegated Acts; mandate CEN/CENELEC harmonised standards; create a single EU-wide UGV/UAV roadmap.

EU Level (primary) • Short-to-medium-term (2026–2028) • DG GROW, DG ENER, CEN/CENELEC, EASA

2 ENABLE ACCESS: Financial Instruments and Market Development

Challenge: High upfront costs, especially in AgriPV and FPV, create a two-tier market favouring large operators; TaaS offers a pathway but needs regulatory and financial enablement.

Key actions: Dedicated EIB/InvestEU sub-window for autonomous O&M; expand Horizon Europe/LIFE+ funding for underserved contexts; recognise autonomous O&M as CAP Pillar II / NECP-eligible; promote TaaS regulatory sandboxes.

EU + Member State Level • Short-to-medium-term (2026–2028) • European Commission, EIB, DG AGRI, DG ENER

3 BUILD TRUST: Workforce Transition, Data Governance and Social Acceptance

Challenge: Deployment raises legitimate workforce and community concerns, while autonomous systems generate vast operational data with no clear ownership or access framework.

Key actions: JTF/ESF+ pathways for O&M workforce upskilling and certification; mandatory data governance framework aligned with the Data Act and GDPR; privacy-by-design procurement standards; standardised community engagement toolkits.

EU + Member State Level • Medium-term (2027–2029) • DG EMPL, DG CNECT, ESF+ Authorities

4 PROTECT AND CO-EXIST: Environmental and Ecological Standards

Challenge: New technology-environment interactions (fire risk, soil/biodiversity impact, avifauna effects on FPV energy yield) are not addressed by regulation calibrated to autonomous O&M's footprint.

Key actions: EU environmental guidelines per PV deployment type under the EIA Directive; standardised FPV ecological monitoring protocol; incorporate AgriPV O&M into Biodiversity Strategy/Farm to Fork guidance; EU wildlife-management guidance note; standardised LCA methodology.

EU Level • Medium-term (2027–2029) • DG ENV, EEA, CEN/CENELEC

5 STANDARDISE: Common Technical and Data Standards Across the Single Market

Challenge: Absent common technical standards fragment the market and lock O&M data into proprietary formats, preventing interoperability.

Key actions: Mandate CEN/CENELEC harmonised standards (aligned with IEC 62446-2) covering safety, certification, data interoperability and training; open data standards in the EU Energy Data Space; minimum cybersecurity standards aligned with ENISA/NIS2.

EU Level (CEN/CENELEC + Commission) • Medium-to-long-term (2027–2031) • CEN/CENELEC, ENISA, DG GROW, DG ENER

From Evidence to Action: How TALOS Contributes

These recommendations are grounded in real-world demonstration activity across three European solar PV contexts, and have been validated by the TALOS consortium. The European Commission and member state regulators are invited to engage directly with the TALOS consortium to take these recommendations forward.

What TALOS has demonstrated:

- **Technology readiness:** UAV + UGV + AI decision support validated and ready across all three contexts.
- **Safety validation:** safe autonomous operation in real solar park environments.
- **Economic evidence:** comparative autonomous vs. manual O&M cost, efficiency and yield data.
- **Environmental integration:** wildlife management measures piloted and monitored at the FPV site.
- **Social evidence:** human-robot interaction and community acceptance research across all pilots.
- **Cross-national comparability:** multi-country regulatory data informing this brief's fragmentation analysis.

ACTION TIMELINE

Short-term (2026–2027): ASREI classification, UAS O&M category, AgriPV definition, FPV permit framework.

Medium-term (2027–2029): Financial instrument, data governance framework, CEN/CENELEC standards, FPV ecological standard.

Long-term (2029–2031): Full open data standards; cross-sector certification scheme.

NEXT STEPS

European Commission: commission a regulatory mapping study; include AgriPV in CAP/RED III review; engage EASA on FPV permits.

Member States: pilot regulatory sandboxes; develop national AgriPV licensing frameworks; engage with the TALOS coordinator and policy working group.

Industry & Standards Bodies: engage CEN/CENELEC on ASREI standards; engage with the TALOS coordinator and policy working group.

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About TALOS

TALOS (robotics and Artificial intelligence Living labs improving Operations in PV Scenarios) is a Horizon Europe-funded project (Grant Agreement No. 101119744) developing and validating autonomous robotic solutions for solar PV inspection, cleaning and maintenance across three deployment contexts: land-based PV, agrivoltaics and floating PV.



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 [INFO@TALOSPROJECT.EU](mailto:info@talosproject.eu)



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