

FLEX INDUSTRIES

INDUSTRIAL FLEXIBILITY IN PRACTICE

Innovation Handbook

How six European plants turned energy use into flexibility

November 2026

Funded by
the European Union

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1.THE CHALLENGE: INDUSTRIAL FLEXIBILITY IN THE ENERGY TRANSITION

Europe's energy system is being rebuilt around wind and solar power, and its industry sits at the centre of that shift. **Industry consumes 27% of all EU energy**; energy-intensive sectors alone use more than half of that. The 2021-22 energy crisis showed how exposed these industries are: **electricity prices rose by more than 400%**, peaking above €500/MWh. At the same time, a grid fed by variable renewables increasingly needs consumers who can adapt by shifting load, storing energy and giving flexibility back to the system. The FLEXIndustries project starts from this double pressure.

1.1. A POWER SYSTEM IN TRANSFORMATION

Three facts frame the challenge:

CLIMATE TARGETS ARE SET

the EU aims for a 55% emission cut by 2030 and climate neutrality by 2050, with industrial decarbonisation (chiefly electrification) as a main lever.

MARKETS WERE BUILT FOR A DIFFERENT ERA

electricity markets were designed around large, dispatchable power plants. To keep the system stable, demand, renewables and distributed generation must now participate actively; continental Europe alone needs around 3,000 MW of frequency reserve at all times.

VOLATILITY IS THE NEW NORMAL

in 2022, day-ahead electricity prices in the project's demo countries averaged between €167 and €294/MWh, with swings of up to €150/MWh. For inflexible consumers this is a risk; for flexible ones, a revenue opportunity.

1.2. WHY INDUSTRIAL FLEXIBILITY MATTERS

Demand-side flexibility is the ability of energy users to change their consumption or generation quickly, in response to prices or grid needs.

Industry is well placed to provide it: industrial loads are highly automated, respond quickly and precisely, and hold built-in storage in the form of thermal inertia, buffers and batch scheduling.

The value at stake is systemic. According to estimates cited by the industry association SmartEn, integrating demand-side flexibility into EU electricity markets could lift energy cost savings **from 43% to 66% by 2027**. Industries can capture this value in two ways:

EXPLICIT DEMAND RESPONSE

Selling flexibility directly in wholesale, balancing and reserve markets.

IMPLICIT DEMAND RESPONSE

Optimising consumption against price signals, hour by hour.

1.3. WHAT HOLDS INDUSTRY BACK

AVAILABILITY FEES FOR INTERRUPTIBLE LOADS

€68,000

per MW per year in Germany

€80,000

per MW per year in Italy

None

no dedicated mechanism in Bulgaria

TECHNICAL LIMITS

Whether an asset can provide flexibility depends on three parameters: ramp rate, start-up time and power output. Steam turbines need hours for a cold start; heat pumps are not built for frequent switching; small units must be aggregated to reach market minimum bid sizes.

ECONOMICS

Flexible capacity often does not match what markets and network operators require, and the most direct incentive remains the electricity price signal.

OPERATIONS

Production always comes first. Flexibility is bounded by process constraints, from non-interruptible furnaces to vehicle charging that cannot be stopped once started.

REGULATION

Rules differ enormously across Europe. Germany pays availability fees of €68,000/MW per year for interruptible loads and Italy around €80,000/MW per year, while Bulgaria and Greece has no dedicated mechanism at all (2023).

1.4. THE MISSING TOOLBOX

When the project surveyed the market in 2023, it found only two commercially relevant flexibility-management tools, both partial: neither combined forecasting, market participation nor real-time optimisation.

The scientific literature confirmed the gap: energy management models able to control power flows cost-efficiently while respecting industrial process constraints were lacking.

This is the gap FLEXIndustries set out to close.



1.5. INNOVATION HIGHLIGHT AND IMPACT

INNOVATION HIGHLIGHT

FLEXIndustries addresses a **key market gap** by bringing forecasting, flexibility management and real-time optimisation together in an integrated digital environment. Its market survey essentially found two commercial flexibility-management tools, neither covering forecasting, market bidding and real-time optimisation together. The project's answer is an **integrated approach** (a shared method, enabling technologies and a digital platform) built around real industrial constraints.

IMPACT SNAPSHOT

~3,000 MW

of frequency reserve is needed in continental Europe at all times: a market industrial flexibility can serve.

7 sectors

All seven energy-intensive sectors analysed by the project can already access balancing markets through service providers or aggregators.

From 43% to 66%

The expected growth of EU energy cost savings by 2027 once demand-side flexibility is fully integrated into electricity markets.

1.6. KEY TAKEAWAYS

Industry consumes 27% of EU energy: industrial flexibility is a structural lever of the energy transition.

The 2021-22 crisis pushed up electricity prices by **over 400%**. That volatility is a risk for inflexible plants and a revenue source for flexible ones.

Demand-side flexibility could lift EU energy cost savings **from 43% to 66% by 2027**, according to estimates cited by SmartEn.

Regulation is a decisive barrier: demand-response remuneration ranges from €68,000/MW per year in Germany to no dedicated mechanism in Bulgaria.

2

2. THE FLEXINDUSTRIES APPROACH

Before technologies and platforms, industry needs a rigorous way to know how much flexibility it actually has, what it is worth and what it must never touch, because production always comes first. The FLEXIndustries approach moves through three connected stages: **measure, establish indicators, implement**.

2.1. THE VISION

An industrial base that treats flexibility as a product: quantified, bankable and traded, without ever compromising production, quality or safety.

The project tested this vision across seven energy-intensive sectors and demonstrates it today in **six real plants** (automotive, polymers, pharmaceuticals, steel, biofuels, fertilisers).



AUTOMOTIVE



POLYMERS



PHARMACEUTICALS



STEEL



BIOGAS / BIOFUELS



FERTILISERS

2.2. FIRST, MEASURE: THE FLEXIBILITY ASSESSMENT

Every demonstration site went through the same structured assessment:

a four-part questionnaire covering energy carriers, market knowledge and quantitative data on generation, manageable loads and storage;

energy and emission baselines (electricity, fuels, CO_2, on-site generation), refined through staged review meetings;

constraints identified for every candidate action, so that flexibility never conflicts with production.

The headline conclusion: **all the industries analysed can already participate in electricity balancing markets** through balancing service providers or aggregators. The potential is real and accessible today. At the Bulgarian steel plant alone, the assessment identified **228 MWh** of manageable next-day consumption per day, enough to cover **96% of the penalties** the plant would otherwise pay for deviating from its forecast consumption.

BULGARIAN STEEL PLANT

228 MWh

manageable next-day consumption per day

96%

of deviation penalties covered

2.3. THEN, PROVE IT: A COMMON MEASUREMENT FRAMEWORK

To make every claim verifiable, the project established a framework of key performance indicators in **five categories** (principal, flexibility, technological, environmental and non-technical), co-designed with each site's research partner. **Three pillar indicators** anchor it:

- total **renewable energy** produced on site;
- total **waste heat** recovered;
- total **energy stored** on site.

Flexibility itself is measured as the **deviation of power consumption from the baseline**, which turns an abstract concept into a quantified, monetisable service. Beyond energy, the framework also tracks jobs created, skills developed, replication potential, safety and cybersecurity.

2.4. FINALLY, IMPLEMENT: SITE BY SITE

No single setup fits every plant.

Technologies were sized to each plant's surfaces, demands and operating limits, and the digital tools follow the same logic: price forecasting is not deployed where electricity prices are fixed, and real-time optimisation runs as simulation where automation is absent.

The result is **one method, one platform and six different, realistic implementations**.



2.5. INNOVATION HIGHLIGHT AND IMPACT

INNOVATION HIGHLIGHT

Measurement comes first.

Rather than declaring flexibility targets, FLEXIndustries began by quantifying what each plant can safely offer (for example, 228 MWh of manageable next-day consumption per day at the Bulgarian steel demonstration) and then built the indicator framework that makes every subsequent claim verifiable.

IMPACT SNAPSHOT

6 sites

Six demo sites in six countries, spanning automotive, polymers, pharmaceuticals, steel, biofuels and fertilisers.

7 sectors

Seven energy-intensive sectors assessed, all found able to access balancing markets today.

96%

of consumption-deviation penalties at the steel demonstration could be covered by the manageable load identified in the assessment.

2.6. KEY TAKEAWAYS

FLEXIndustries built a **replicable flexibility assessment framework**: structured questionnaires, energy baselines and constraint analysis at every site.

Measurement rests on **three pillars** (renewables produced, waste heat recovered, energy stored), plus social and safety indicators.

Flexibility is defined as the **deviation of consumption from the baseline**: a service that can be measured, priced and sold.

Implementation is **tailored per site**. The method is common; the deployment is never forced.

3

3. THE CORE SOLUTION: PLATFORM & INTELLIGENCE LAYER

At the centre of FLEXIndustries sits the **Dynamic Energy & Process Management Platform**: a digital environment that gathers plant data, forecasts what comes next (prices, consumption, renewable production) and turns those forecasts into optimised operating plans. The platform brings together advanced forecasting, optimisation and decision-support capabilities, demonstrated through tailored applications across the FLEXIndustries industrial sites. And it runs today: **since 2025 it has been deployed in the cloud**, secured end to end, producing live optimisations for a real pharmaceutical plant.

3.1. WHAT THE PLATFORM IS

Designed to an international architecture standard, the platform is organised in **four layers**, each answering a simple question:

DATA

How do we connect to plant sensors and external services, reliably and in real time?

MODELLING

How do we represent each process as a simulation that mirrors reality?

PERCEPTION

What will happen next? AI algorithms forecast energy demand, prices, renewable availability and costs.

PLANNING AND OPERATION

What should we do about it, both in long-term planning and in day-to-day operation?

3.2. SIX DIGITAL BRAINS

The platform's decision core is a set of **six decision-support modules**, deployed at each site only where they make sense:

PROCESS DATA FORECASTING

Predicts energy-related variables from plant machinery and sensors.

PRICE FORECASTING

Predicts day-ahead electricity prices from market data such as gas and carbon prices.

FLEXIBILITY FORECASTING

The one module used at every site, estimates how much load can be shifted or switched off, and when.

PROCESS PLANNING

An offline tool that weighs technology upgrades and load shifting against cost, efficiency and carbon.

THE MARKET MODULE

Turns available flexibility into optimal bids on energy and flexibility markets, tested against a commercial market simulator.

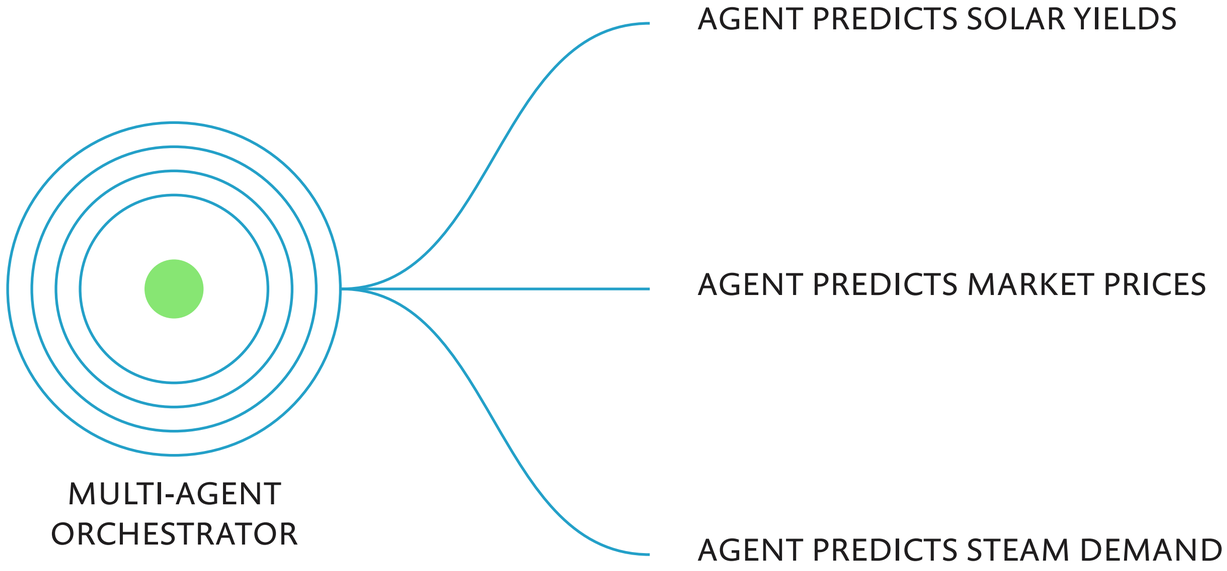
REAL-TIME OPTIMISATION

Adjusts operations close to real time, built on digital twins of the physical equipment.

3.3. AI THAT WORKS AS A TEAM

Every forecasting or optimisation model is an **independent software agent**: one predicts solar yields, another market prices, another steam demand.

A **multi-agent orchestrator** coordinates them. It breaks each request into tasks, feeds every agent the data it needs and combines the results into a single outcome. Because each agent stands alone, partners could develop their modules independently and plug them in. The system also looks after itself: when a model's accuracy drifts, it is **retrained automatically**, without interrupting service.

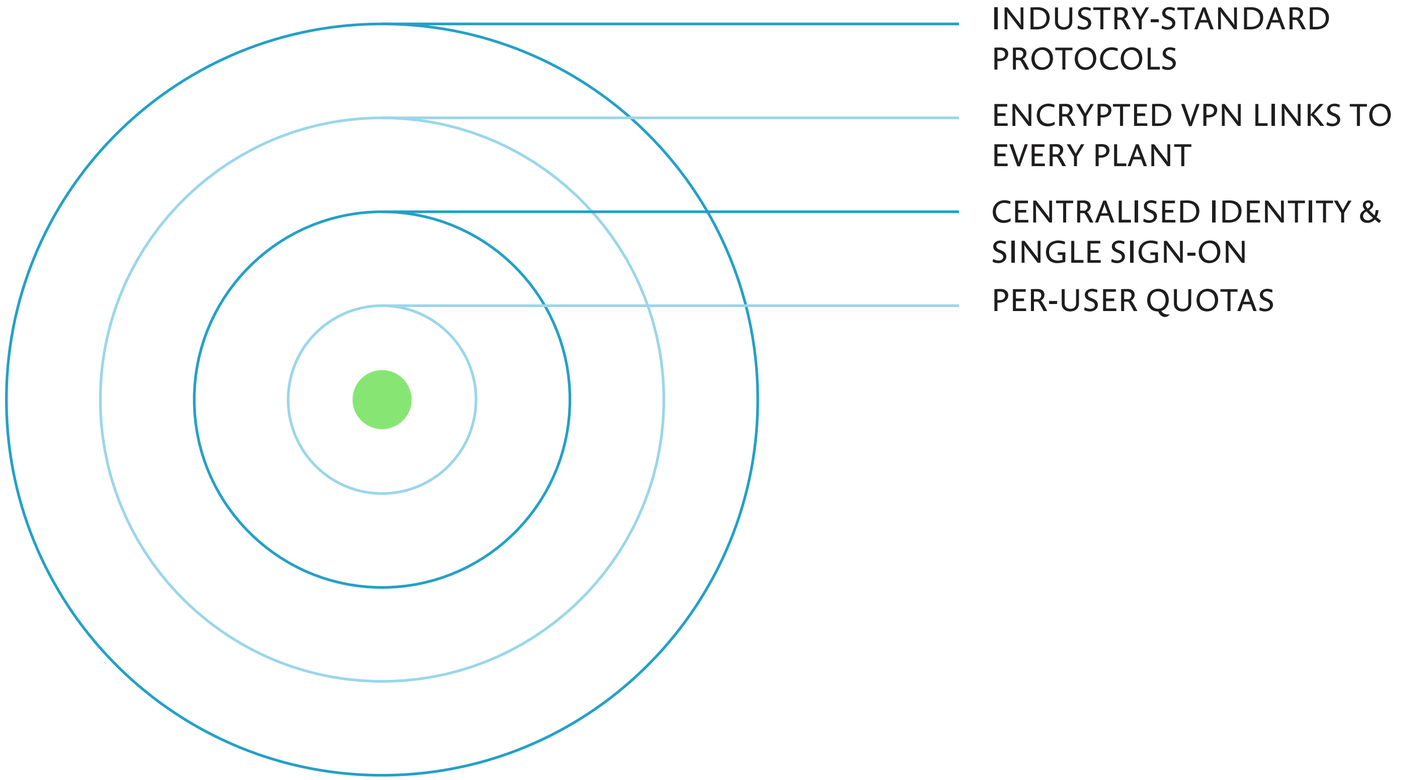


3.4. SECURE AND CONNECTED BY DESIGN

The platform connects to factories through **industry-standard protocols**, with encrypted virtual private network links to every plant's data sources.

Access is governed by centralised identity management and single sign-on, with per-user quotas that block excessive or malicious requests.

Security is built in as one of the platform's structural layers.



3.5. UP AND RUNNING

The platform **runs in production** on a cloud cluster and is publicly reachable at flex.linksfoundation.com.

Its flagship demonstration is a pipeline of **seven cooperating agents**: six parallel forecasters (for electricity, gas and solar prices, and for electricity, steam and water demand) feeding a process-planning optimiser.

For the fermentation process at the Italian pharmaceutical demonstration, the pipeline produces next-day optimised plans in **about five seconds**, on an hourly schedule.

THREE APPLICATIONS COMPLETE THE OFFER:

LCA-LCC tool

A scenario simulator linking energy consumption to costs and CO_2, letting a plant compare efficiency measures before investing; tested on real data for 2024 the first half of 2025 from the Turkish demo.

Expert training

E-learning environment with seminars, interviews, tool documentation, to keep serving industry after the project ends.

Collaboration space

An open online forum where industrial users exchange experience, organised by sector.

3.5. UP AND RUNNING

Three applications complete the offer:

LCA-LCC TOOL

A scenario simulator linking energy consumption to costs and CO_2, letting a plant compare efficiency measures before investing; tested on real data for 2024 and the first half of 2025 from the Turkish automotive demonstration.

EXPERT TRAINING

An e-learning environment with seminars, interviews and tool documentation, designed to keep serving industry after the project ends.

COLLABORATION SPACE

An open online forum where industrial users exchange experience, organised by sector.

3.6. INNOVATION HIGHLIGHT AND IMPACT

INNOVATION HIGHLIGHT

Running in production.

Six parallel forecasting agents and a process-planning optimiser, developed by three different partners, cooperate in a single pipeline that turns plant data into a next-day optimal plan for a pharmaceutical fermentation process in about five seconds. Deployed on a secured cloud cluster, scheduled hourly, with modules reusable across the other demonstration sites.

IMPACT SNAPSHOT

~5 s

End-to-end execution of the seven-agent optimisation pipeline on the live platform.

24 h

Every 24 hours: automatic re-assessment of key operational parameters by the optimisation and predictive-maintenance modules.

2024 baseline

Tested on a real factory: the LCA-LCC tool built a full 2024 energy, cost and CO_2 baseline of the automotive demonstration and compared it with monitoring data for the first half of 2025.

3.7. KEY TAKEAWAYS

The platform **addresses a key market gap** by bringing forecasting, flexibility management and real-time optimisation together in an integrated digital environment.

Six decision-support modules, from price forecasting to real-time optimisation, are deployed per site, only where they make sense.

Independent AI agents, developed by different partners, cooperate through one orchestrator and retrain themselves when accuracy drifts.

It runs in production: live, secured and optimising a real pharmaceutical process every hour.

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4. THE ENABLERS: TECHNOLOGIES FOR INDUSTRIAL FLEXIBILITY

Digital intelligence needs physical assets to act on. Across the six demonstration plants, FLEXIndustries designed and installed a **portfolio of enabling technologies**, each sized on the specific surfaces, demands and operating limits of its host plant. Together they give industry the **physical levers of flexibility**: renewable generation to shift around, storage to decouple consumption from production and waste-heat recovery that turns losses into useful energy.

4.1. ENERGY STORAGE

4 sites
with batteries or thermal storage

200 kWh
battery with 100 kW power, Spain

40 m³
hot-water tank, Poland

Storage is what makes energy use movable in time. Batteries and thermal solar were deployed at four sites:

ITALY (PHARMACEUTICALS)

Eight battery racks of 51.2 kWh each, managed by a dedicated energy management system.

SPAIN (FERTILISERS)

A 100 kW / 200 kWh battery integrated with the plant's solar generation. Decision-support software recommends to operators, based on market prices, whether to store solar energy or use it directly.

BULGARIA (STEEL)

A battery of about 50 kWh coupled to a waste-heat power unit, designed to decide dynamically whether to self-consume, store or sell electricity; both are installed and undergoing commissioning.

POLAND (POLYMER INSULATION)

A 40 m³ hot-water tank buffering the plant's solar thermal field.

4.2. RENEWABLE GENERATION ON SITE

3.68 MWp
solar PV across two plants, Turkey

500 kWp
rooftop solar, Italy

635 m²
solar thermal field, Poland

TURKEY

3.68 MWp of solar PV across two plants (a 1.18 MWp rooftop plant of 2,612 panels at Gölcük and a 2.5 MWp plant at Yeniköy), which produced about 3.8 GWh between August 2025 and July 2026, all self-consumed on site, plus two solar air-heating walls totalling 3,960 m² (1,560 m² and 2,400 m²) that preheat ventilation air by up to 20 °C and are estimated to deliver around 1,470 MWh of heat per year.

ITALY

A 500 kWp rooftop solar plant, projected to produce about 572 MWh per year.

POLAND

A 635 m² field of 324 high-vacuum flat plate (HVFP) solar thermal collectors, simulated to deliver about 428 MWh of useful heat per year. The solar thermal system at K-FLEX preheats the makeup water at 60°C before it enters the boilers of the EPS production line that started operation in September 2024. TVP Solar SA is the HVFP technology provider.

4.3. WASTE HEAT PUT TO WORK

150 kWel
nominal output of each ORC unit

~480 t
CO_2 saved per year, Greece

~989 t
CO_2 saved per year, Bulgaria

Industrial plants throw away enormous amounts of heat. FLEXIndustries recovers it in **four different ways**:

ELECTRICITY FROM WASTE HEAT (GREECE)

An Organic Rankine Cycle unit of a nominal power output 150 kWel (a technology that generates electricity from low-temperature heat) recovers the waste heat rejected from the biogas engine cooling water and flue gases, using a low-GWP working fluid (R1234ze(E)). Estimated saving: around 480 tonnes of CO_2 per year, assuming 4,000 operating hours.

ELECTRICITY FROM FURNACE GAS (BULGARIA)

A second Organic Rankine Cycle unit of a nominal power output 150 kWel exploits steel-furnace flue gas at 350 to 380 °C through a 1.8 MW heat exchanger. Expected saving: around 989 tonnes of CO_2 per year.

4.3. WASTE HEAT PUT TO WORK

~40%
heat-transfer loss in two months of tests, Poland

514 t
CO_2 saved per year, Poland

1 MW
air-preheating heat exchanger, Spain

SELF-CLEANING HEAT RECOVERY (POLAND)

When contaminated flue gas made the original plan unviable (tests showed heat transfer degrading by almost 40% in two months), the project pivoted to a heat exchanger. The core of the new installation is a heat exchanger designed specifically for this application, with a self-cleaning function and easy maintenance at shutoffs. To the partners' knowledge, it is the first heat exchanger dedicated for the rubber industry that can operate under such heavy contamination. Expected saving: about 137,000 m^3 of natural gas and 514 tonnes of CO_2 per year.

AIR PREHEATING FROM BIOMASS STEAM (SPAIN)

A 1 MW heat exchanger preheats dryer combustion air from 15°C to 120°C, already installed and operational.

One more enabler deserves its own mention.

At the Italian site, a **high-temperature heat pump** is designed to produce 989 kW of cooling for the plant and 1,255 kW of heating at up to 93°C, simultaneously. The recovered and upgraded heat is intended for export to the town's **district heating network**, once heating-season demand allows start-up. The heat pump uses R515B, a non-flammable refrigerant with low global-warming potential.

4.4. CONNECTED TO THE PLATFORM

6 of 6
sites run flexibility forecasting

2
batteries dispatched on market-price forecasts (Spain, Bulgaria)

These installations are the **actuators of the flexibility** that the platform manages.

Battery dispatch in Spain and Bulgaria is designed to follow market-price forecasts; flexibility forecasting runs at every site; and the platform's optimisation pipelines convert forecasts of prices, renewable production and process demand into next-day plans that the assets execute.

4.5. INNOVATION HIGHLIGHT AND IMPACT

INNOVATION HIGHLIGHT

At the Polish demonstration, two months of testing showed heat-transfer rates fell by almost 40% as flue-gas contaminants condensed and solidified on the exchanger surfaces.

The planned ORC unit could not work under these conditions, so K-Flex and Lodz University of Technology replaced it with direct heat recovery. The core of the new installation is a heat exchanger designed specifically for this application, with a self-cleaning function and easy maintenance. To the partners' knowledge, it is the **first heat exchanger dedicated to this industry** that can operate under such heavy contamination.

IMPACT SNAPSHOT

3.68 MWp

and ~3.8 GWh produced between August 2025 and July 2026, all self-consumed: the solar PV plants at the automotive demonstration.

~1,470 MWh

per year of solar heat estimated from 3,960 m² collector walls.

514 t

~137,000 m³ of natural gas and 514 tonnes of CO_2 saved per year expected at the Polish demonstration.

~2,000 t

of CO_2 avoided per year expected from waste-heat recovery across three plants.

4.6. KEY TAKEAWAYS

Six plants received **tailor-designed technologies**: solar power and heat, batteries, a high-temperature heat pump, waste-heat exchangers and two waste-heat power units.

Waste heat becomes electricity: two 150 kW units are expected to avoid around 1,500 tonnes of CO_2 per year combined.

One heat pump, two products: designed to deliver 1,255 kW of district heating for the town and 989 kW of cooling for the plant at the same time.

Storage links generation to flexibility: batteries at three sites, designed to be dispatched on market-price forecasts.

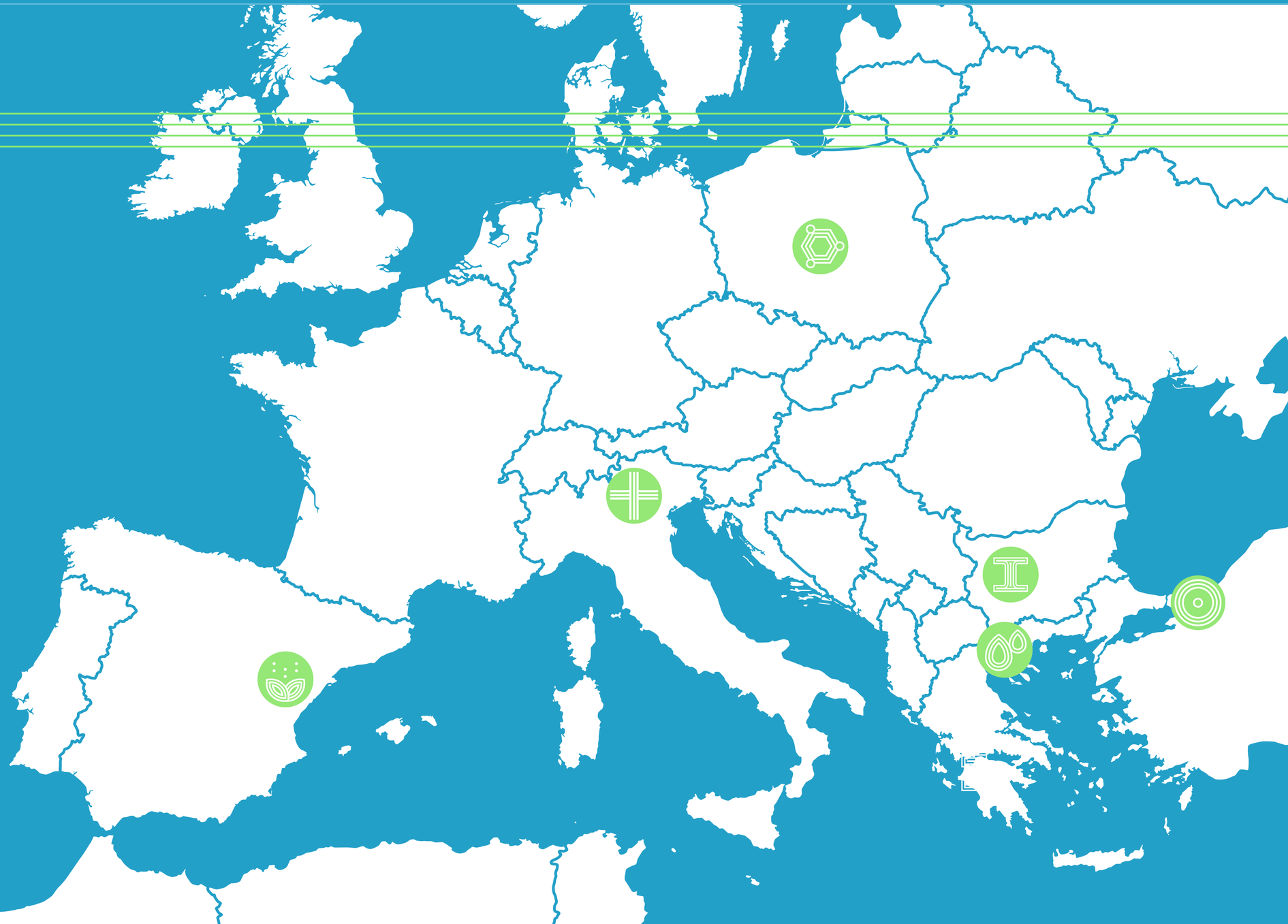
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5. FLEXINDUSTRIES IN ACTION: DEMONSTRATIONS ACROSS INDUSTRIES

FLEXIndustries validates its approach where it matters: **on the factory floor**. **Six plants in six countries** host the project's technologies and digital tools under real production conditions, and each poses a different flexibility problem, from shiftable electric loads at an automotive plant to contaminated waste heat at a polymer factory. The profiles below summarise each demonstration.

5.1. DEMOS' MAP

- Automotive, Turkey
- Polymer insulation, Poland
- Pharmaceuticals, Italy
- Steel, Bulgaria
- Biogas / biofuels, Greece
- Fertilisers, Spain



5.2. THE SIX DEMONSTRATION SITES AT A GLANCE

DEMO SITE	SECTOR / COUNTRY	KEY TECHNOLOGIES	HEADLINE EXPECTED IMPACT
FORD Otosan p. 37	Automotive, Turkey	3.68 MWp solar PV (two plants); 3,960 m² solar air-heating wall	~3.8 GWh of solar power produced Aug 2025–Jul 2026, all self-consumed; ~1,470 MWh/yr of solar heat (estimate)
K-Flex p. 38	Polymer insulation, Poland	635 m² solar thermal + 40 m³ storage; self-cleaning heat-recovery exchanger	~137,000 m³ of gas and 514 t of CO_2 saved per year
Suanfarma Italia p. 39	Pharmaceuticals, Italy	500 kWp solar PV; ~410 kWh battery; 1 MWth double-effect high-temperature heat pump	~572 MWh/yr of solar power; HTHP and DH connection installed, start-up linked to heating-season demand. Expected water savings thanks to HTHP cooling.
Stomana Industry p. 40	Steel, Bulgaria	150 kW waste-heat power unit on steel furnace waste heat stream; ~50 kWh battery coupled to it	~989 t of CO_2 avoided per year expected; installed, undergoing commissioning
MIL Oil Hellas p. 41	Biogas / biofuels, Greece	150 kW waste-heat power unit on biogas engine waste heat	~480 t of CO_2 avoided per year (estimate)
Fertinagro Nutrigenia p. 42	Fertilisers, Spain	100 kW / 200 kWh battery; 1 MW air-preheating heat exchanger	Exchanger: 534 MWh of heat in 982 hours, 39.54 t of natural gas and 107.83 t of CO2 saved (Jan–Jul 2026); both systems installed, exchanger operational

Table 1: The six FLEXIndustries demonstration sites at a glance

5.3. FORD OTOSAN: AUTOMOTIVE, GÖLCÜK (KOCAELI), TURKEY

AUTOMOTIVE
TURKEY

3.68 MWp
solar PV across two plants (Gölcük and Yeniköy)

3.8 GWh
solar electricity produced between August 2025 and July 2026

THE CHALLENGE

One of Europe's largest commercial-vehicle plants, with major electricity and heat demand from its body, paint and assembly shops, plus growing electric-vehicle charging loads.

THE SOLUTIONS

3.68 MWp of solar PV across two plants (a 1.18 MWp rooftop plant of 2,612 panels at Gölcük and a 2.5 MWp plant at Yeniköy) and two solar air-heating walls totalling 3,960 m² (1,560 m² and 2,400 m²) that warm ventilation air by up to 20°C.

THE RESULTS

About 3.8 GWh of solar electricity produced between August 2025 and July 2026, all self-consumed on site, and around 1,470 MWh of solar heat per year, as an indicative estimate. The plant also served as the test case for the platform's cost-and-carbon (LCA-LCC) simulation tool, which compared a full 2024 baseline with monitoring data for the first half of 2025.

5.4. K-FLEX: ELASTOMERIC THERMAL INSULATION, POLAND

POLYMER INSULATION POLAND

635 m²
high-vacuum solar thermal field

~428 MWh
solar heat expected per year

514 t
CO_2 saved per year (expected)

THE CHALLENGE

Furnace exhaust gases heavily contaminated with substances that condense and solidify on heat-exchange surfaces (tests measured a near-40% loss of heat transfer within two months), combined with variable process temperatures and scarce cooling water.

THE SOLUTIONS

A 635 m² high-vacuum solar thermal field with a 40 m³ storage tank, and direct waste-heat recovery from three furnaces, which replaced the originally planned ORC unit. Lodz University of Technology designed the installation around a dedicated self-cleaning heat exchanger, built for heavily contaminated flue gas and easy to maintain in this industry.

THE RESULTS

About 428 MWh of solar heat expected per year, up to 150 kW of recovered furnace heat feeding process water and silo heating, and expected savings of about 137,000 m³ of natural gas and 514 tonnes of CO_2 per year. The installation is currently being commissioned due to delays connected with amendment and additional work connected with design of the specific purpose heat exchanger.

5.5. SUANFARMA ITALIA: PHARMACEUTICALS, ROVERETO, ITALY

PHARMACEUTICALS
ITALY

500 kWp
rooftop solar plant

~572 MWh
solar electricity projected per year

1,255 kW
design heating output at up to 93°C for the town

THE CHALLENGE

A pharmaceutical-ingredient site with simultaneous, energy-intensive heating and cooling demand from fermentation, air compression, refrigeration and solvent recovery.

THE SOLUTIONS

A 500 kWp rooftop solar plant; a 240 kW/409 kWh battery system of eight racks under a dedicated energy management system; and a 1 MWth high-temperature heat pump designed to deliver 989 kW of cooling to the plant and 1,255 kW of heating at up to 93°C to the town's district heating network.

THE RESULTS

About 572 MWh of solar electricity projected per year, and installed capacity for simultaneous heating and cooling: the heat pump and its connection to the town's district heating network have been built and an agreement with the network operator is in place, with start-up linked to heat demand in the heating season. The plant's production process is also the live use case of the platform's seven-agent optimisation pipeline, which produces next-day plans in about five seconds.

5.6. STOMANA INDUSTRY: STEEL, PERNIK, BULGARIA

STEEL
BULGARIA

150 kWel
ORC unit, nominal output

1.8 MW
heat exchanger for heat recovery

~989 t
CO_2 saved per year

THE CHALLENGE

A steel plant exposed to electricity-market volatility, with high-grade waste heat leaving its furnace as flue gas at 350 to 380°C.

THE SOLUTIONS

An Organic Rankine Cycle (ORC) unit of nominal power output of 150 kWel driven by waste heat using a 1.8 MW heat exchanger for heat recovery and a pressurised hot-water loop, coupled with a battery of about 50 kWh.

THE RESULTS

The ORC unit and the battery are installed and integrated, and are undergoing commissioning after a fault during trial runs (insufficient water flow in one circuit); performance data are not yet available. The expected saving is about 989 tonnes of CO_2 per year. Modelling (TRL 6–7) shows that a battery dispatched on forecast day-ahead prices could reduce the penalties the plant pays for deviating from its forecast consumption.

5.7. MIL OIL HELLAS: BIOGAS AND BIOFUELS, SERRES, GREECE

BIOGAS / BIOFUELS
GREECE

150 kW
ORC unit, nominal output

2.4 MW
recoverable heat from the biogas engines (1.5 to 2.4 MW)

100°C
hot water from the engines, max.

THE CHALLENGE

Valorising the waste heat of biogas engines (hot water at up to 100°C carrying 1.5 to 2.4 MW of recoverable heat) in a plant where biodiesel production takes priority.

THE SOLUTIONS

An Organic Rankine Cycle (ORC) unit of nominal power output of 150 kW driven by biogas engine's cooling circuit designed around a high-efficiency expansion concept and a working fluid with near-zero global-warming potential, engineered and installed at the plant.

THE RESULTS

The ORC system is installed and operational, with fluid and power flows continuously monitored. Between February and August 2026 it ran for 1,745 hours, generating 99.4 MWh of net electricity and recovering 3,411 MWh of heat. Average load was 57 kWel against a design output of 150 kWel, because engine hot water reached 92.3°C instead of 100°C and the condenser fouled. It turns industrial waste heat into valuable electricity, demonstrating waste-heat recovery under real conditions. Data-driven models built from these measurements lay the groundwork for real-time optimisation and predictive control of industrial ORC systems.

5.8. FERTINAGRO NUTRIGENIA: FERTILISERS, UTRILLAS, SPAIN

FERTILISERS
SPAIN

200 kWh
battery storage, 100 kW

1 MW
air-preheating heat exchanger

120°C
dryer combustion air, from 15°C

THE CHALLENGE

Reducing natural-gas consumption in the plant's thermal drying process and making the plant's new solar PV generation dispatchable; i.e., able to be stored and used when it is most valuable, rather than only available for immediate self-consumption.

THE SOLUTIONS

A 100 kW / 200 kWh battery energy storage system (BESS), integrated with the on-site PV plant and supported by the project's decision-support software, which recommends to operators when to charge the battery from solar surplus and when to discharge it, to cover the plant's own demand, based on electricity price signals. In parallel, a 1 MW heat exchanger preheats the dryer's combustion air from 15°C to 120°C using steam drawn from the existing biomass boiler, reducing the amount of natural gas required to reach drying temperature.

THE RESULTS

The heat exchanger is fully installed and operational, with steam flows continuously monitored, and is already reducing natural-gas consumption and the associated CO_2 emissions. The integrated PV and battery system enables smarter energy management, helping the plant make better use of renewable generation and respond to electricity price signals.

5.9. KEY TAKEAWAYS

Six real plants in six countries demonstrate the full FLEXIndustries chain: assessment, enabling technologies and platform-driven operation.

Results are already measurable: the Turkish solar PV plants produced about 3.8 GWh in twelve months, the Spanish heat exchanger is operational, and the optimisation pipeline runs live for the Italian plant.

The demonstrations prove **adaptability** as much as technology. The Polish redesign shows the approach absorbing real industrial constraints without losing its impact targets.

6

6. FROM INNOVATION TO ADOPTION

Demonstration is not an end in itself. For FLEXIndustries, success means industrial flexibility becoming an **adopted practice**: technologies that reach the market, a platform that outlives the project and a blueprint other plants, in Europe and beyond, can replicate.

6.1. THE VALUE PROPOSITION FOR INDUSTRY

20
US states where flexible electrolyser operation makes hydrogen cost-competitive

Value
stacking across four revenue streams

INDUSTRIAL SITES ARE EXCELLENT PROVIDERS OF FLEXIBILITY.

They are highly automated, fast and precise in response (more so than households or electric vehicles), and they hold built-in storage in thermal inertia, buffers and batch scheduling. The revenue logic is **value stacking**: capacity payments, activation payments, energy arbitrage and avoided peak charges, assessed against full costs over an asset's lifetime.

FLEXIBILITY CAN MATERIALLY CHANGE PLANT ECONOMICS.

Research presented in the project's transatlantic workshops showed that flexible electrolyser operation makes hydrogen production cost-competitive in 20 US states under 81 retail electricity rates. What makes industrial flexibility bankable is discipline: quality, safety and process constraints always outrank flexibility revenue.

VALUE STACKING

Capacity payments
Activation payments
Energy arbitrage
Avoided peak charges

6.2. FROM RESULTS TO MARKETS

2028
market entry: battery + EMS solution and heat pump

2030
novel waste-heat power unit

2,700+
energy service companies in the European market

Beyond the demonstration phase, FLEXIndustries is paving the way for wider industrial adoption through a portfolio of innovative technologies, digital solutions and transferable approaches, opening up opportunities for commercial uptake, replication and further development. Its key results include:

The **digital platform** and its optimisation algorithms, laying the foundations for service-based solutions supporting smarter and more flexible industrial energy management;

The **integrated battery-plus-energy-management** solution and the **high-temperature heat pump** with low-GWP refrigerant, **offering opportunities for more efficient and flexible industrial energy use**;

Waste-heat-to-power solutions for industrial applications, highlighting the potential **to recover otherwise unused energy and improve energy efficiency**; an **integrated industrial solar thermal system** (installation completed; performance validation to follow), energy-system models that include flexible industries, and **new business models** for industrial flexibility.

A stakeholder analysis identifies who matters for each result (customers, partners, suppliers, enablers and supporters) in a European market that counts 43 transmission system operators, over 900 distribution system operators and more than 2,700 energy service companies. **Grid operators, energy service companies and aggregators** emerge as the key players almost everywhere; they are the gateway between industrial flexibility and the grid.

6.3. A BLUEPRINT THAT TRAVELS

5
leading US institutions

~100 GW
new flexible loads the US grid could integrate

12 GW+
shiftable load across major US industrial facilities

Through its international cooperation programme, the consortium established collaboration with **five leading US institutions** (Duke University, the University of Wisconsin-Madison, Princeton University, the University of Colorado Boulder and the National Renewable Energy Laboratory) and co-developed **eleven best practices** for industrial flexibility, covering the full lifecycle:

mapping flexibility potential and characterising processes, because intuitive estimates usually overstate what a plant can offer;

modular assets, electrification, digitalisation and forecasting;

optimisation, market integration and flexibility across energy carriers;

protecting quality, safety and process constraints: the plant's core mission always comes first;

sound economics, fair contracts, organisational readiness, and monitoring and verification.

They form a coherent **conceptual framework** for industrial flexibility. The transatlantic evidence underlines the scale of the prize: research presented in the project's workshops estimates that **nearly 100 GW** of new flexible loads could be integrated into the US grid using existing capacity, and quantifies **more than 12 GW** of shiftable load across major US industrial facilities.

6.4. FUTURE OUTLOOK

EU

flexibility needs assessments at national and European level

US

planned engagement with the Department of Energy

POLICY

The policy environment is moving in the project's direction: the reformed EU electricity market design introduces **flexibility needs assessments** at national and European level, complemented by the EU's action plan on affordable energy and its work on capacity mechanisms.

COOPERATION

The cooperation agenda continues with planned engagement with the US Department of Energy and reciprocal research visits.

KNOWLEDGE

Beyond the project's end, the **training environment** built on the platform is designed to keep conveying its knowledge (seminars, interviews and tool documentation) to the next generation of adopters.

6.5. INNOVATION HIGHLIGHT AND IMPACT

INNOVATION HIGHLIGHT

A transatlantic knowledge bridge.

FLEXIndustries turned international cooperation into a concrete asset: bilateral work with Duke, Wisconsin-Madison, Princeton, Colorado Boulder and NREL produced eleven co-reviewed conceptual best practices, from flexibility-mapping templates to monitoring-and-verification baselines, that any energy-intensive plant can apply.

IMPACT SNAPSHOT

~100 GW

of new flexible loads could be integrated into the US grid using existing capacity, according to research presented in the project's workshops.

6 demos

Six industrial demonstration sites across six countries, showcasing adaptable approaches to industrial energy flexibility.

12 GW+

More than 12 GW of shiftable load quantified across major US industrial facilities.

2,700+

43 transmission operators, 900+ distribution operators and 2,700+ energy service companies: the European network that will carry industrial flexibility to market.

6.6. KEY TAKEAWAYS

Industrial flexibility is a business case: value stacking across capacity, activation, arbitrage and avoided charges, with production, quality and safety always protected.

A diverse portfolio of innovative technologies, digital solutions and business models offers opportunities for wider industrial adoption, replication and future development.

Eleven conceptual best practices co-developed with five US institutions form a coherent conceptual framework for industrial flexibility.

EU policy is converging on the same agenda: the reformed electricity market design introduces flexibility needs assessments across Europe.



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