OGGETTO: AVVISO MANIFESTAZIONE DI INTERESSE PER LA SELEZIONE DI OPERATORI ECONOMICI PER L'AFFIDAMENTO DIRETTO – PREVIO CONFRONTO PREVENTIVI, SU MEPA, AI SENSI DELL' ART. 50, COMMA 1, LETT. B) DEL D.LGS. N. 36/2023 S.M.I. PER L'AFFIDAMENTO DELLA "FORNITURA E POSA IN OPERA CONFIGURAZIONE E MESSA IN ESERCIZIO DI N.48 DISPOSITIVI Iot DI CUI N.16 DISPOSITIVI DI MONITORAGGIO ECOFISIOLOGICO DELLA PIANTA E N.32 DISPOSITIVI DI RILEVAZIONE FIAMME E ALLARME PRECOCE PER LA PREVENZIONE RISCHIO INCENDI NELL'AMBITO DEL PROGRAMMA DI COOPERAZIONE TERRITORIALE EUROPEA INTERREG VI-GREECE-ITALY 2021-2027 DENOMINATO OFIDIAPlus - CUP F63C25000840008.

ALLEGATO 1
SPECIFICHE TECNICHE

OFIDIAPlus Project

Technical Specifications for the Tender for the Procurement of Sensors in the Calabria Region

Cooperation Programme 632 - (Interreg VI-A) Greece-Italy
Project: OFIDIAPlus - 6005141

Summary

1 OFIDIAPlus Project Summary

The primary objective of the OFIDIAPlus project is to develop and implement an integrated cross-border environmental monitoring and early warning system for forest ecosystems exposed to climate-related risks, with particular focus on wildfire prevention, ecosystem resilience, and climate adaptation strategies in the eligible areas of the Interreg cooperation programme.

The project promotes the deployment of innovative digital technologies and transnationally coordinated monitoring infrastructures through pilot actions implemented in representative forest and protected natural areas. OFIDIAPlus relies on advanced environmental sensing technologies, wireless sensor networks (WSNs), cloud-based data infrastructures, and data-driven analytical approaches to support continuous ecosystem monitoring and risk assessment in Mediterranean forest environments increasingly affected by climate change.

The digital monitoring infrastructure developed within the project includes Internet of Things (IoT) environmental sensors, wildfire detection systems, wireless communication technologies, cloud-based data management systems, and integrated visualization platforms. These technological components operate collaboratively to provide continuous, high-frequency monitoring of forest ecosystem dynamics, environmental stress conditions, and wildfire risk factors, enabling both preventive actions and rapid emergency response.

The proposed monitoring infrastructure is based on integrated IoT environmental sensing systems capable of operating autonomously in forest environments for extended periods without human intervention. The monitoring devices are designed to acquire high-resolution environmental, atmospheric, and ecophysiological data through distributed wireless sensor networks (WSNs).

The deployed monitoring units shall support continuous ecosystem assessment through multi-parameter measurements including spectral vegetation analysis, sap flow dynamics, radial growth monitoring, microclimatic conditions, air quality parameters, thermal anomalies, and wildfire-related atmospheric indicators.

The integrated monitoring approach allows the generation of both preventive risk indicators and direct alarm signals associated with wildfire ignition and propagation.

A key objective of the project is to strengthen climate resilience and environmental protection capacities through the implementation of innovative and interoperable monitoring solutions capable of supporting institutional actors, civil protection authorities, forest managers, and environmental agencies in the prevention and management of wildfires. In particular, the project contributes to improving wildfire prevention strategies through real-time environmental monitoring, early warning mechanisms, and integrated decision-support approaches.

By effectively monitoring pilot forest sites located within the eligible cooperation areas, the OFIDIAPlus infrastructure aims to achieve, among others, the following objectives:

1. Developing integrated environmental monitoring systems for continuous assessment of forest ecosystem health, vegetation stress, and wildfire risk conditions.

2. Implementing distributed wireless sensor networks and real-time data acquisition infrastructures to support early warning and rapid detection of wildfire events.
3. Supporting climate adaptation and ecosystem resilience strategies through the collection, integration, and analysis of environmental, ecophysiological, and atmospheric data.
4. Enhancing cross-border cooperation and interoperability among institutional stakeholders involved in environmental monitoring, forest management, and civil protection activities.

In relation to these project goals, this particular procurement aims to realize the supply, installation, and operational deployment of IoT forest monitoring and wildfire detection sensors, which directly support the implementation of the OFIDIAPlus environmental monitoring infrastructure.

In particular one pilot site will be covered in the Calabria Region: "Pineta di Curinga".

The IoT sensors are procured and deployed as a core and indispensable component of the OFIDIAPlus wireless monitoring network. They enable the continuous acquisition of environmental, atmospheric, and ecophysiological parameters within forest ecosystems, producing pre-alarm information associated with vegetation stress, drought conditions, tree stability, fuel dryness, and local microclimatic variability. These measurements are essential for the early identification of conditions potentially associated with increased wildfire susceptibility and ecosystem vulnerability under climate change scenarios.

In addition to continuous environmental monitoring, the deployed sensors are designed to generate event-based alarm data in the presence of anomalous or hazardous conditions, including measurements related to gas concentrations, particulate matter, thermal anomalies, flame detection, and image-based wildfire confirmation. Through the integration of pre-alarm and alarm functionalities, the monitoring infrastructure supports proactive risk assessment, early warning generation, and timely operational response to wildfire events.

The sensor network operates as a distributed wireless infrastructure ensuring reliable transmission of IoT data toward centralized cloud-based storage and processing systems through communication technologies such as NB-IoT and LoRa. In line with the overall project architecture, the collected data are integrated into shared digital infrastructures supporting real-time visualization, historical analysis, environmental assessment, and the development of advanced risk evaluation methodologies.

The procured IoT monitoring systems therefore directly contribute to the operational deployment of the OFIDIAPlus environmental monitoring platform by ensuring continuous and event-driven environmental data flows required to establish an effective and interoperable cross-border forest monitoring and wildfire prevention network in cooperation with the project partners and institutional stakeholders.

2 OFIDIAPlus Pilot Site: Curinga Pine Forest

The Curinga Pine Forest (Pineta di Curinga) is a protected natural area located along the Tyrrhenian coast of Calabria, famous for its blend of Mediterranean scrub and wide sandy beaches. Situated in the municipality of Curinga (Catanzaro province), it is

easily accessible via the SS18 highway or the A2 motorway (exits: Lamezia Terme or Pizzo).
The Curinga Pine Forest represents one of the largest coastal forest systems in the province of Catanzaro and it represents an important natural habitat and an area of great ecological value for coastal biodiversity.

Key Features:

- *Natural Environment*: A dense expanse of maritime pines stretching right to the edge of the sea.
- *Activities*: It is an ideal spot for rejuvenating walks, birdwatching, and outdoor sports, featuring several dirt trails perfect for trekking or cycling.
- *Curinga Beach*: The forest acts as a natural barrier to a massive public beach known for its clear waters and peaceful atmosphere, even during peak season.

Surrounding Areas include:

- Inhabited centers and productive areas;
- Main roads connecting the city center;
- Sports and recreational areas;
- Roman Baths of Acconia: An exceptionally well-preserved Imperial-era thermal complex (1st-2nd century AD) situated just a few minutes from the coast;
- Mezza Praia Tower: A historic coastal watchtower that dominates the shoreline between Curinga and Lamezia Terme.

The area is characterized by:

- coastal pine forests;
- Mediterranean scrub;
- coastal sandy areas;
- presence of nature trails and paths.

The predominant species are:

- stone pine:
- maritime pine;
- Aleppo pine;
- mastic tree;
- myrtle;
- broom.

Wildfire risks

The pine forest area is frequented by residents and tourists, especially during the summer season.
It includes: forest roads, nature trails, access to the coast, rest areas, tourist facilities in the surrounding areas, nearby beach resorts.
The presence of tourist infrastructure increases the risk of fires during the summer months. The pine forest is considered a high-risk area for several reasons:

- large presence of resinous conifers;
- accumulation of dry material on the forest floor;
- coastal winds that favor the spread of flames;
- large summer tourist population.

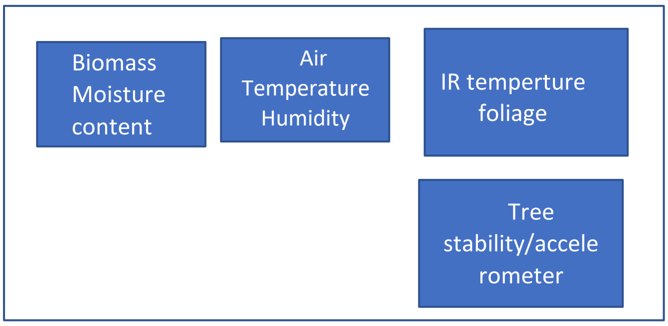
Over the past ten years, the coastal area of the province of Catanzaro has been affected by several fires involving similar coastal pine forests.

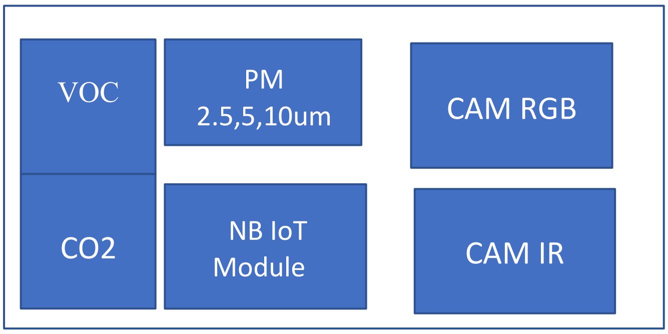
3 Wireless sensor networks

In the OFIDIAPlus project, the proposed wireless sensor network platform consists of a set of two integrated IoT units designed for forest ecosystem monitoring and early wildfire detection.
The first unit (**Prevention Device**) is dedicated to tree physiological and environmental monitoring, while the second unit (**Fire Device**) is dedicated to wildfire detection and alarm generation.

The functional structure of the two units are described below.

PREVENTION DEVICE **FIRE DEVICE**





The **Prevention Device** is designed to simultaneously measure multiple tree-scale ecophysiological parameters with additional ecosystem-related variables. The key parameters are solar radiation over 28 bands covering VIS (visible) and NIR (infrared) areas, growth, tree stability, sap flow, and microclimate data.
In particular, it contains:

1. A spectrometer featuring 28 spectral bands from 410 to 1000 nm, covered by an optical light diffuser – cosine corrected for measuring canopy light transmission;
2. A sap flow probe measurement system using heat pulse velocity algorithms;
3. A 0.5 µm resolution (10 µm absolute error) electronic point dendrometer for radial growth detection;
4. An air temperature and relative humidity sensor;

5. An accelerometer for the assessment of the inclination of the trunk in x, y and z directions.

Each sensor can also be deployed as a stand-alone monitoring device if required by operational conditions.
Data are usually measured hourly and collected data are made available remotely through NB-IoT or LoRa technologies. LoRa Wan or NB-IoT connectivity is user selectable at the time of purchase. Additionally, NB-IoT is more efficient for distant distributed trees (distance between them more than 600 m). NB-IoT version is provided with a 10-year prepaid sim card (500 MB). LoRa version needs a reachable gateway that will forward data packets to a server. LoRa solution performs better for region with weak internet signal or for numerous devices where the cost of the gateway is rewarded by the minor cost of the devices (over 30 devices).
For each device at least 50% more batteries than the number of devices is suggested in order to make batteries change easier. A battery charger is required as well.

A **Fire Device** should be installed within the same geographical area to provide calibration and reference measurements for spectral analyses. It must be installed in the same geographical area of the installed devices to serve as a reference spectrum for solar radiation measurements.
The Fire Device integrates flame and smoke detectors together with RGB imaging systems for real-time fire alarm and fire evolution monitoring. In particular the device contains:

1. IR camera for flame detection (110°x75° field of view, 0.1K RMS @1Hz);
2. RGB camera 3 Mpx with SD card;
3. Particulate Matter detection (from 0.3 to 10 µm laser operated, not binned in classes). Range is 0-1000µg/m, Accuracy ±15µg/m³ for 0- 100 µg /m³, ± 15% Reading for 101-1000 µg/m³;
4. Total VOC and Index of air quality IAQ. Data is qualitative on the basis of the factory calibration. [1]
5. CO2 concentration Range; 400-5000 ppm, accuracy: 50ppm;
6. IR foliage temperature sensor (8-14**µ**m, ±0.2 °C).

The Fire Device can operate in integrated mode with the physiological monitoring unit and share the same wireless communication infrastructure.

The overall Integrated Forest Monitoring Platform is powered by rechargeable lithium battery systems, and recharging batteries are supposed to be within a 4-6 months cycle, depending on environmental conditions.

3.1 Pre-alarm and alarm parameters, risk index and health status

The Integrated Forest Monitoring Platform classifies its measurements into pre-alarm parameters (early indicators of stress or fire risk) and alarm parameters (direct fire detection).

3.1.1 Pre-Alarm Parameters from Prevention Device

These indicators monitor tree and environmental health to assess potential fire risk:

[1] https://www.bosch-sensortec.com/en/products/environmental-sensors/gas-sensors/bme690#technical

- **Sap Flow Density**: Sap flow density represents the rate at which water is transported through the tree's vascular system. It is a direct indicator of plant physiological activity and water uptake from the soil. Reduced sap flow typically indicates water stress, drought conditions, or impaired root function. Since water availability is crucial for maintaining plant hydration, low sap flow values are associated with increased vegetation dryness and, consequently, higher fire susceptibility.
- **Stem humidity**: Stem humidity refers to the internal moisture content of the tree trunk. It reflects the hydration status of woody tissues and is strongly influenced by environmental conditions such as rainfall and temperature. Low stem humidity indicates dry biomass, which is more easily ignitable. This parameter is therefore critical in assessing fuel conditions within forest ecosystems.
- **Relative Air Humidity**: Relative air humidity expresses the amount of water vapor present in the air relative to the maximum it can hold at a given temperature. Low humidity conditions promote rapid drying of vegetation and organic material on the forest floor. This significantly increases the likelihood of ignition and enhances fire spread potential.
- **Air Temperature**: Air temperature is a key environmental variable influencing evapotranspiration and vegetation dryness. High temperatures accelerate water loss from both soil and plants, leading to dehydration of biomass. Prolonged periods of elevated temperatures contribute to critical fire weather conditions and increase ignition probability.
- **Water Spectral band** (normalized to 940/900): This parameter is derived from optical measurements of vegetation reflectance in the near-infrared region. It is sensitive to changes in leaf water content and canopy structure. Variations in this ratio can indicate early signs of plant stress, dehydration, or physiological changes before they become visually detectable.
- **Nir/Red ratio**: The ratio between near-infrared (NIR) and red reflectance is widely used to assess vegetation vigor. Healthy vegetation strongly reflects NIR light while absorbing red light due to chlorophyll activity. A decrease in this ratio indicates reduced photosynthetic efficiency and plant stress, often associated with drought or disease.
- **Normalized Difference Vegetation Index (NDVI)**: NDVI is a standardized vegetation index calculated from red and near-infrared reflectance. It provides a quantitative measure of vegetation greenness and photosynthetic activity. High NDVI values correspond to dense, healthy vegetation, while low values indicate sparse, stressed, or dry vegetation. It is one of the most widely used indicators for monitoring ecosystem health and fire risk.
- **Vapour Pressure Deficit (VPD)**: VPD represents the difference between the amount of moisture in the air and the amount it can hold when saturated. It is a key indicator of atmospheric drying power. High VPD values indicate strong evaporative demand, forcing plants to lose water more rapidly. This leads to increased physiological stress and contributes to the drying of fuels, thereby elevating fire risk.
- **Radial Growth**: Radial growth measures the expansion of the tree trunk over time, typically detected using dendrometers. It reflects long-term physiological performance and resource availability. Reduced or stagnant growth is often a sign of environmental stress, such as drought or poor soil conditions, which can weaken vegetation and increase vulnerability to fire.
- **Tree trunk axis movement**: Tree trunk movement is monitored through accelerometers that detect inclination and oscillations along three axes. This parameter provides information on tree stability and mechanical stress caused by wind or environmental disturbances. Abnormal movement patterns may indicate structural weakness or extreme weather conditions, which can indirectly influence fire risk (e.g., through increased fuel accumulation or damage).
- **Health Status** – synthesized index summarizing the tree's overall condition.
- **Pre-Alarm Daily Index** – aggregated indicator of daily fire risk based on the above parameters.

3.1.2 Alarm Parameters

These are direct indicators of fire ignition or propagation:

- **Gas Concentrations (CO2, VOC, IAQ, PM 2.5–PM10)** – measured by sensors to detect smoke and fire emissions. This sensor measures the concentration of airborne particles within a specific size range, typically associated with smoke. A sudden increase in particulate matter indicates combustion processes and the presence of smoke, even before flames are visible. It is a critical early indicator of fire activity. VOC concentration can increase as a result of photochemical reactions during combustion processes. Low IAQ values levels may indicate the presence of fire-related emissions or atmospheric pollution. While not a direct fire indicator, it contributes to environmental monitoring and detection accuracy. Carbon dioxide concentration rises significantly during combustion. Monitoring CO_2 levels allows detection of burning processes, particularly in smoldering fires where flames may not yet be visible. It is a reliable indicator of active or developing fire conditions.
- **Flame Flag (serial number)**: The flame flag is a binary indicator associated with the device serial number that signals the detection of a fire event. When activated, it confirms that the system has identified thermal signatures consistent with flames through the infrared sensing system. This parameter is used to trigger alarms and to associate the detected event with a specific monitoring unit.
- **Leaf Temperature** – measured by IR sensors, reflects water stress.
- **RGB Image** - The RGB camera captures high-resolution visual images of the monitored area. It is used to confirm fire events detected by other sensors and to track the spatial and temporal evolution of the fire. It also supports situational awareness and post-event analysis.
- **IR Image (Flame Detection)** - The infrared (IR) camera detects thermal radiation emitted by flames. It enables rapid identification of fire ignition even under low visibility conditions such as smoke or darkness. This parameter provides real-time detection of active fires, allowing for immediate response.
- **RGB flag:** The RGB flag is a diagnostic indicator used to verify the successful transmission of RGB images. It is checked against incoming data streams:
    - If the flag confirms reception, the system is operating correctly.
    - If no image is received (e.g., the daily test image is missing), it indicates a potential malfunction in the camera or communication system.

  In such cases, the issue should be reported to Nature 4.0 for further investigation.
- **Alarm Daily Index** – aggregated daily indicator of fire occurrence based on all alarm parameters.

3.2 Data Flow

The system operates through a multi-layered monitoring and data processing framework designed to support both environmental assessment and early fire detection in near real time.

- **Hourly Monitoring:** Continuous acquisition of ecophysiological and environmental parameters, including sap flow, radial growth, air temperature and humidity, spectral indices, tree stability, leaf temperature, particulate matter (PM), ozone, and CO_2.
- **Trigger Monitoring (every 15 minutes):** Infrared (IR) fire sensors provide early warning signals by detecting thermal anomalies associated with potential fire ignition.
- **Emergency Monitoring (continuous / every 5 minutes):** Cameras, IR fire detection systems, and gas/particulate sensors deliver high-frequency, real-time data to confirm fire events and support operational response.

Data are continuously collected and transmitted to the cloud via wireless communication technologies such as NB-IoT or LoRa toward centralized cloud-based data infrastructures. Processed data are stored in dedicated cloud-based databases at the CMCC HPCC supercomputing center, ensuring both real-time accessibility and long-term historical analysis. An interactive web-based dashboard provides dynamic visualization tools, enabling users to monitor environmental conditions and support timely and informed decision-making.

4 Sensors distribution in the Calabria Region

The number and type of sensors to be acquired are as follows, **for a total of 48 sensors**

Type of sensor	Number of sensors	Installation site	Positioning
Prevention Device	16	Pineta of Curinga	Anchoring on plant
Fire Device	32	Pineta of Curinga	Anchoring on plant

5 Technical requirements of sensors

A) n. 16 Prevention Devices

Dispositivo sensoristico di prevenzione e monitoraggio eco-fisiologico della pianta – specifiche tecniche	
Requisiti tecnici minimi per componenti e sensoristica	• Spettrometro con 28 bande spettrali nell'intervallo 410–940 nm, con diffusore ottico corretto al coseno; • sistema di misura del flusso linfatico basato su algoritmi Heat Pulse Velocity; • dendrometro con risoluzione 0,5 µm ed errore assoluto 10 µm; • sensore di temperatura e umidità relativa dell'aria; • accelerometro triassiale per la misurazione dell'inclinazione del tronco lungo i tre assi x, y e z;
Modalità di acquisizione/trasmissione dati	• Acquisizione ordinaria dei dati con frequenza almeno oraria; • trasmissione remota tramite tecnologie NB-IoT o LoRaWAN; • disponibilità dei dati su infrastruttura cloud/server per successive elaborazioni, visualizzazione e analisi.

B) n. 32 Fire Devices

Dispositivo sensoristico di rilevazione incendio e allarme precoce – specifiche tecniche	
Requisiti tecnici minimi per componenti e sensoristica	• Telecamera IR per rilevazione fiamma con campo visivo 110° x 75° e sensibilità 0,1 K RMS @ 1 Hz; • telecamera RGB 3 Mpx con scheda SD; • sensore PM laser per particolato da 0,3 a 10 µm, range 0–1000 µg/m³, accuratezza ±15 µg/m³ per 0–100 µg/m³ e

	±15% per 101–1000 µg/m³; • sensore ozono range 10–1000 ppb, accuratezza 1 ppb; • sensore CO_2 range 400–5000 ppm, accuratezza 50 ppm; • sensore IR temperatura foglia/chioma 8–14 µm, accuratezza ±0,2 °C.
Modalità di acquisizione/trasmissione dati	• Monitoraggio ordinario dei parametri atmosferici e ambientali; • monitoraggio trigger della presenza di fiamma con frequenza fino a 15 minuti; • in caso di rilevazione fiamma, acquisizione e trasmissione di immagini RGB verso server/cloud per conferma evento e supporto alle operazioni; • trasmissione dati tramite infrastruttura wireless condivisa, con tecnologie NB-IoT o LoRaWAN.

C) Posa in opera, configurazione e messa in servizio

La posa in opera dovrà essere effettuata secondo modalità compatibili con le caratteristiche eco-fisiologiche degli alberi e con la tutela dell'ecosistema forestale, assicurando il corretto posizionamento dei dispositivi di prevenzione e monitoraggio eco-fisiologico e dei dispositivi di rilevazione e allarme precoce nei punti individuati dalla Stazione Appaltante o concordati in fase esecutiva.
L'operatore economico dovrà garantire l'installazione, il fissaggio, la configurazione, la calibrazione e la messa in esercizio dei sensori, minimizzando l'impatto sulle piante e assicurando la piena funzionalità della trasmissione dati e dei sistemi di allerta.
L'installazione del sistema dovrà essere effettuata presso le aree boschive e naturali indicate nella **Sezione 2. OFIDIAPlus Pilot Site: Curinga Pine Forest di questo documento**.
Si precisa che, trattandosi di siti forestali estesi su superfici di diversi ettari, le sedi di installazione non corrispondono a singoli immobili, fabbricati o punti fisici univoci, ma a porzioni territoriali diffuse all'interno delle aree individuate.
I dispositivi dovranno pertanto essere collocati in più punti dei siti boschivi interessati, secondo una distribuzione funzionale alla copertura delle aree da monitorare, alla rilevazione dei parametri eco- fisiologici e ambientali, nonché all'allerta precoce in caso di fumo, fiamme o altri indicatori di combustione.
I punti esatti di installazione saranno definiti in fase esecutiva, d'intesa con la Stazione Appaltante e, ove necessario, con i soggetti competenti per la gestione delle aree, tenendo conto delle caratteristiche morfologiche dei luoghi, della presenza di alberature idonee, dell'accessibilità per le attività di posa e manutenzione e delle esigenze di copertura della rete di comunicazione dati.
La fornitura si intenderà completata esclusivamente a seguito dell'avvenuta installazione, configurazione e messa in esercizio del sistema, nonché del positivo esito del test funzionale, della verifica della corretta acquisizione e trasmissione dei dati e dell'accertamento del corretto funzionamento delle funzioni di monitoraggio, rilevazione e allarme precoce.
L'operatore economico dovrà garantire i servizi di manutenzione dei sensori per n. 6 (sei) anni dall'installazione nonché lo smontaggio a fine progetto dei sensori stessi che dovranno essere riconsegnati alla Stazione Appaltante che li affiderà successivamente alla Regione Calabria in comodato d'uso.
Il completamento della fornitura comprende altresì la consegna della documentazione tecnica, della manualistica d'uso e di ogni ulteriore documentazione necessaria alla gestione operativa del sistema.

Clausola di equivalenza:
In conformità all'Allegato II.5, del D.Lgs. 36/2023, qualsiasi riferimento a marchi, brevetti, tipologie o specifici produttori è puramente indicativo e finalizzato a descrivere il livello minimo di prestazioni richiesto.