Tech Tip Thursday

Construction Surveying • Earthworks • Siteworks Machine Guidance • Roadworks • ***Groundworks*** *• Marine Construction • Connected Site • Augmented Reality • Office Software*

Date: **14/05/2026**

Prepared by: **Daniel Fernandez - WEN Sales Engineers Manager**

Measurement and evaluation of hammer impact energy during pile installation using Trimble Groundworks machine control system

The application

This tech tip focuses on the measurement and evaluation of hammer impact energy during pile installation using Trimble Groundworks drilling and piling machine control system. In these applications, the energy delivered by each hammer blow is a fundamental parameter governing pile penetration, soil resistance mobilization, and the development of the pile's load-bearing capacity. Accurate measurement of impact energy enables a clear understanding of the efficiency of energy transfer from the hammer to the pile, as well as the stresses induced within the pile and surrounding soil mass.

Monitoring impact energy is essential to verify that field operations are consistent with design assumptions and specified driving criteria. Insufficient delivered energy may result in inadequate penetration or failure to achieve the required bearing capacity, while excessive energy can induce overstressing, potentially leading to structural damage of the pile or degradation of the soil–pile interface. Furthermore, reliable energy measurements support quality control, allow for calibration of predictive methods such as wave equation analyses, and facilitate real-time adjustments to driving parameters. Consequently, the systematic measurement and interpretation of hammer impact energy play a critical role in ensuring the safety, performance, and efficiency of driven piling operations.

The challenge

Measuring hammer impact energy without dedicated instrumentation presents significant practical and technical limitations in driven piling operations. In the absence of a measurement system, energy assessment is typically inferred from indirect indicators such as hammer rated energy, stroke height, fuel settings, or observed pile set per blow. However, these proxies do not account for real energy losses within the driving system, including inefficiencies in the hammer mechanism or misalignment between hammer and pile among others. As a result, the actual energy transferred to the pile can differ substantially from nominal values, introducing uncertainty into the evaluation of driving performance and pile capacity.
Furthermore, without real-time measurement, it is difficult to detect variations in hammer performance or changes in soil resistance during installation. Operators must rely heavily on experience and conservative assumptions, which can lead either to underdriving – risking insufficient bearing capacity – or overdriving, with potential structural damage to the pile. The lack of quantitative data also limits the ability to validate design models, optimize driving parameters, or maintain consistent quality control across a project. Consequently, the absence of dedicated energy measurement technology represents a key challenge, reducing both the accuracy and reliability of driven piling operations.

What does Trimble offer to overcome this challenge?

To address these limitations, Trimble offers a dedicated solution designed to complement its Trimble Groundworks machine control system. This solution consists of an integrated energy measurement module, commonly referred to as an “energy box,” which is installed on the piling rig to capture real-time impact data. The system processes signals tracking the hammer movement inside its cylinder to calculate the actual impact kinetic energy of the hammer at the moment just before impact, providing a direct and reliable measurement rather than relying on indirect estimates. Through seamless integration with the Groundworks field solution, this data is made immediately available to operators and engineers, enabling live monitoring, recording, and analysis of driving performance. As a result, the solution enhances operational transparency, supports data-driven decision-making, and ensures that piling activities are executed in line with design and quality requirements.

What does the sales configuration for this solution look like?

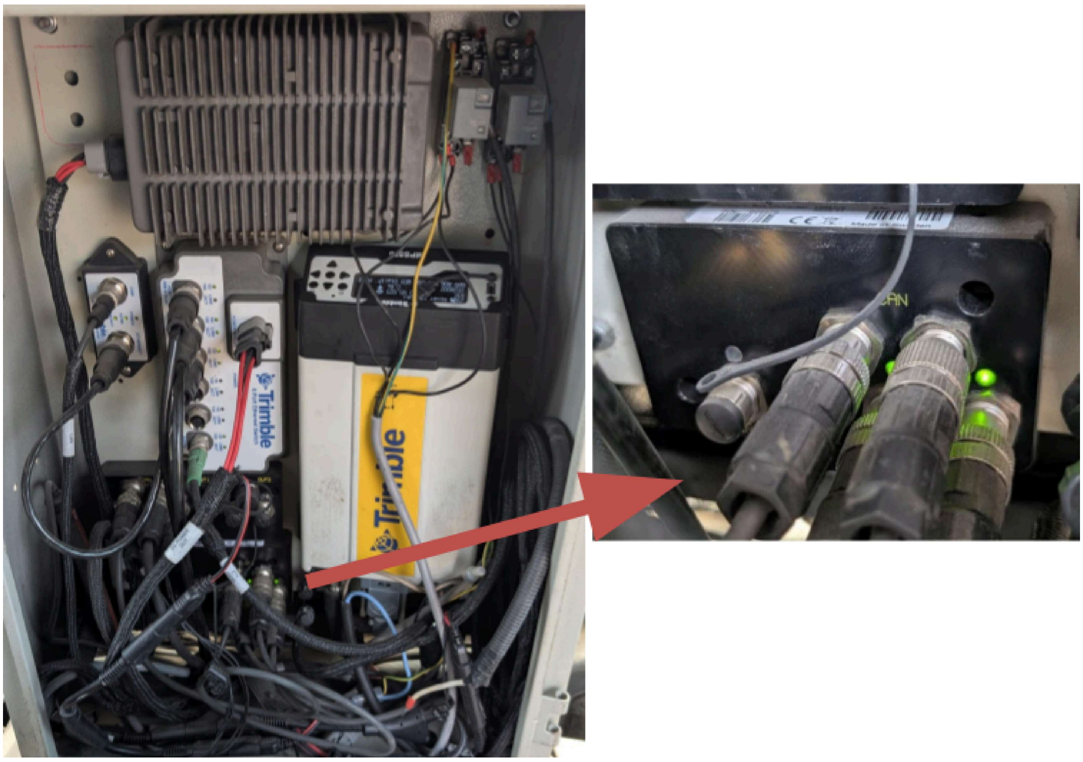
The following table shows the right parts needed to install an Energy Box add-on to an existing Groundworks system

PN	Description	Qty
92314-00	Sensor - PSD900, Proximity Switch, Depth Measurement	1
92295-05	Cable - CAN 5 Core Signal Cable - 5m with protection sleeve	2

Proximity switches included in the PN 92314 kit are PN 98446 PNP type.

The installation

The Energy Box integrates on the Groundworks harness as another sensor on the CAN chain.

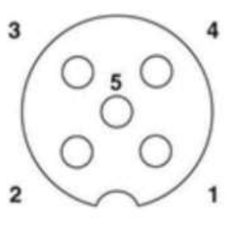


There are two types of inputs available on this interface box: digital inputs and pulse inputs. Both are intended to handle discrete signals, but they are designed for different purposes. A digital input is used to read a signal state – such as ON/OFF, 0/24 V, or presence/absence – and is typically suited for relatively slow or steady signals. However, it is not optimized for detecting rapid transitions or very short-duration events.

In contrast, pulse inputs are specifically designed to measure signal changes over time rather than just their instantaneous state. They can be used for pulse counting, frequency measurement, or determining the time interval between successive signals. Due to their high-speed detection capability, pulse inputs can reliably capture fast transitions and very short pulses, making them more suitable for applications where timing accuracy and signal dynamics are critical, as the one being chased.

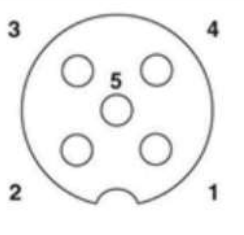
The following table shows how the pin-out connection is done for each case.

Schematic diagram CAN
Pin assignment M12 socket, 5-pos, A-coded, socket side view.



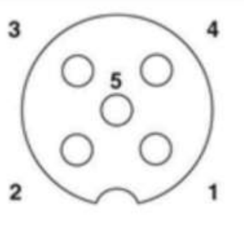
pin - 1	Not Connected
pin - 2	10..30V DC (Supply voltage)
pin - 3	GND
pin - 4	CAN-High
pin - 5	CAN-Low

Schematic diagram Digital in 1, in 2
Pin assignment M12 socket, 5-pos, A-coded, socket side view.



pin - 1	10..30V DC (Supply voltage)
pin - 2	Active low input (Yellow Led)
pin - 3	GND
pin - 4	Active high input (Green Led)
pin - 5	Not Connected

Schematic diagram Pulse in 1, in 2
Pin assignment M12 socket, 5-pos, A-coded, socket side view.



pin - 1	10..30V DC (Supply voltage)
pin - 2	Not Connected
pin - 3	GND
pin - 4	Pulse input (Red Led)
pin - 5	Not Connected

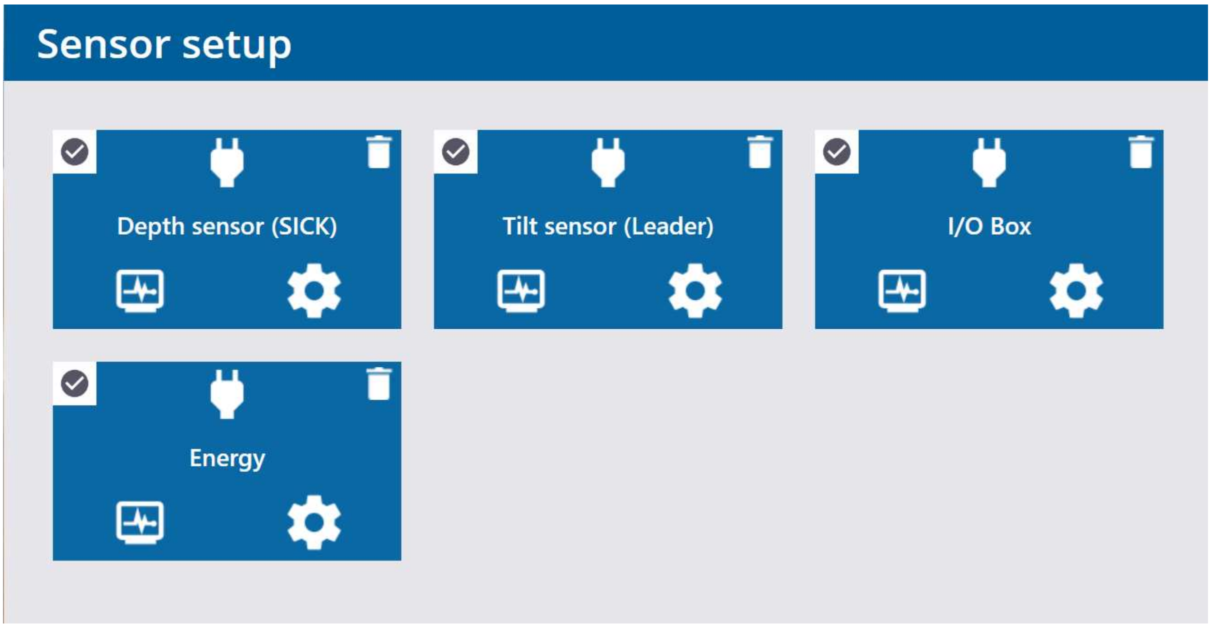
The two proximity switches are installed along the hammer cylinder at positions such that the hammer passes both sensors during every lifting cycle and prior to each blow. The spacing between the two sensors can be selected as required; however, a greater distance generally improves measurement accuracy, provided that the hammer consistently travels above the upper sensor in all operating conditions.

For optimal results, the lower proximity switch should be positioned as close as practicable to the hammer–pile impact point. Where this is not feasible, a configurable offset between the lower sensor position and the actual impact point (referred to as the energy offset) can be applied to account for the remaining travel distance.

Both connect to the *pulse inputs* of the energy box, being the top proximity switch the pulse input number one and the lower the number two.

The configuration

The energy box must be selected as an existing CAN sensor on the sensor setup page. Once added, it can be configured on the sensor settings icon at the bottom right of the tile (sprocket icon).



Both proximity sensors measure the time taken by the hammer to travel between their respective positions, represented on the software as *energy distance*. This allows the calculation of the hammer's downward travel speed (*velocity*), determined from the measured distance between sensors and the elapsed time, where *d* is the distance in meters and *t* is the time in seconds:

$$v = \frac{d}{t}$$

The impact energy of the hammer is defined as its *kinetic energy* at the instant immediately prior to contact with the top of the pile. This is calculated using the *hammer mass* and the previously determined velocity, where *m* is the hammer mass in kilograms and *v* is the velocity in meters per second.

$$E = \tfrac{1}{2}mv^2$$

In this configuration, the velocity used to compute impact energy is measured between the two proximity switches, not exactly at the point of impact. If the lower proximity switch is positioned some distance above the actual hammer–pile contact point, the measured velocity corresponds to the hammer speed at the lower proximity switch location, not at impact.

This distinction matters because the hammer typically continues to accelerate during its downward travel due to gravity (and/or the driving system). As a result, the velocity at the actual impact point is higher than the velocity measured at the lower sensor. If this difference is not accounted for, the calculated kinetic energy will be underestimated.

Placing the lower proximity switch as close as possible to the impact point minimizes this discrepancy, ensuring that the measured velocity more closely represents the true impact velocity. When physical constraints prevent this placement, applying an offset (*energy offset*) allows the system to account for the remaining travel distance between the lower sensor and the impact point. This correction improves the accuracy of the estimated impact velocity and, consequently, the computed impact energy.

If there is a remaining distance between the lower sensor and the impact point the hammer will be still accelerating. The velocity at the impact point *(v2)* will be computed as follows, being *v1* the velocity at the lower proximity switch, *a* the acceleration of the descent and *s* the offset between the lower proximity switch and the impact point *(energy offset):*

$$v_2^2 = v_1^2 + 2as$$

Then the energy at the impact point will be computed as:

$$E = \frac{1}{2} m v_2^2$$

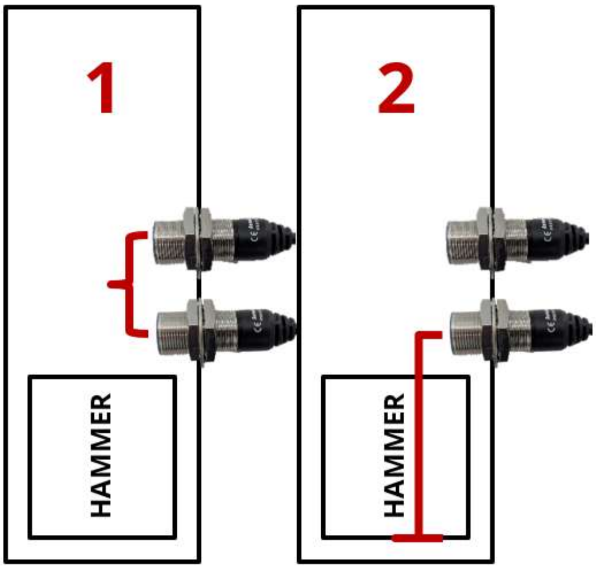
As with any real mechanical system, there is a difference between the theoretical energy calculated from kinematics and the energy actually available at impact. The equations used to estimate velocity and kinetic energy assume ideal conditions – constant acceleration and no losses – whereas, in practice, the hammer motion is influenced by several dissipative effects. These include mechanical friction within the hammer and guiding system, air resistance, hydraulic or diesel inefficiencies, and energy dissipation through seals, cushions, and structural interactions.

To account for these effects, a correction factor – commonly referred to as a *resistance* or *efficiency factor* is introduced. This factor reduces the theoretical energy to better approximate the real energy delivered during operation. It can be applied either at the velocity level or directly to the computed energy, effectively representing the cumulative losses in the system. The value of this factor is typically determined empirically, based on calibration against measured data or known performance characteristics of the hammer, although 10% is a good rough estimation for hydraulic hammers.

By incorporating this adjustment, the estimated impact energy becomes more representative of actual field conditions, improving the reliability of the calculations for monitoring and control purposes.

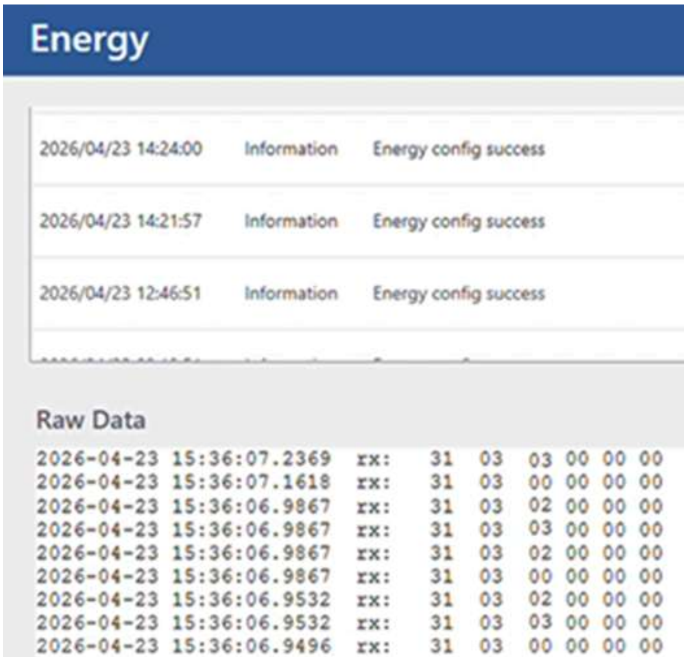
Energy

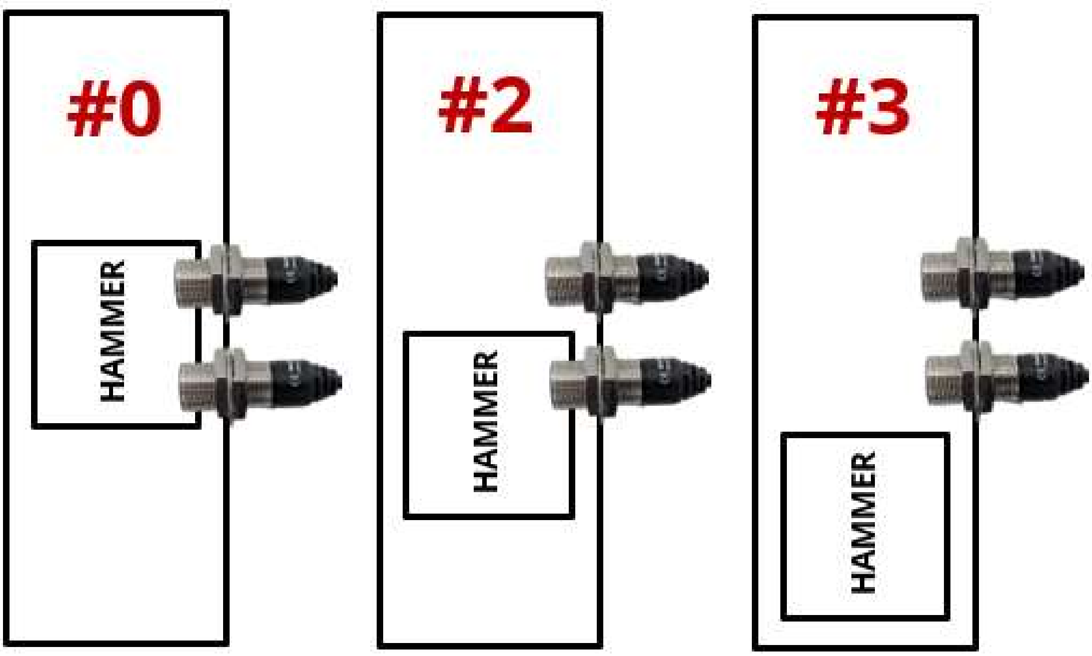
Hammer mass	5000	kg
Energy distance	0.10	m
Energy offset	0.5	m
Resistance	10	%



The diagnosis

For correct operation, the diagnostic signals from the two proximity switches must follow a consistent and logical sequence that reflects the hammer's movement during each blow cycle. When the hammer is on its upper position, meaning loaded for starting a hit, both proximity switches are activated (or will be as the hammer passes along), corresponding to state #0. As the hammer descends and passes the lower proximity switch, only the lower sensor is triggered, producing state #2. At the moment of the impact, none of the sensors are activated, resulting in state #3. The progression #0 #2 #3 defines a complete blow cycle, with the return to state #0 occurring as the hammer is lifted again.





There is a different state (#1) where only the upper sensor is active and may occur when lifting the hammer higher up. This state is not used on blow counting. The counting logic is based on detecting the transition from state 0 to state 2, and then to state 3, at which point the blow is registered. Therefore, even if state 1 appears intermittently, as long as the sequence progresses through #0 → #2 → #3, the system will correctly identify and count a complete hammer blow.

The deliverables

Each hammer blow is automatically recorded by the energy box and stored in the blow count report, providing a detailed log of driving performance over time. For every recorded blow, several parameters are captured. *Distance* represents the penetration achieved during that specific blow, indicating how much the pile advanced into the ground. *Energy* corresponds to the calculated impact energy for that blow, derived from the measured hammer velocity and travel, reflecting the effective force delivered. *Height* refers to the stroke of the hammer, meaning the vertical distance the hammer traveled before impact. Finally, *Interval* relates to the number of blows recorded as part of a refusal or set measurement sequence, typically used to assess soil resistance and pile capacity during driving. Together, these values provide a comprehensive dataset for monitoring installation quality, evaluating performance, and supporting engineering analysis.


```
▼<Blows intervalDistance="0.300" maxBlows="38">
  <Blow date="2026-04-23T09:35:39.7677501Z" distance="5.044" energy="11237.807" height="0.229" interval="0"/>
  <Blow date="2026-04-23T09:35:40.6013430Z" distance="5.079" energy="13338.834" height="0.272" interval="0"/>
  <Blow date="2026-04-23T09:35:41.4329348Z" distance="5.107" energy="9247.271" height="0.189" interval="0"/>
  <Blow date="2026-04-23T09:35:42.2625244Z" distance="5.147" energy="10493.657" height="0.214" interval="0"/>
  <Blow date="2026-04-23T09:35:43.0856089Z" distance="5.187" energy="11492.556" height="0.234" interval="0"/>
  <Blow date="2026-04-23T09:35:43.9107018Z" distance="5.232" energy="12329.806" height="0.251" interval="0"/>
  <Blow date="2026-04-23T09:35:44.7337822Z" distance="5.287" energy="12014.967" height="0.245" interval="0"/>
  <Blow date="2026-04-23T09:35:45.5623696Z" distance="5.348" energy="9421.798" height="0.192" interval="0"/>
  <Blow date="2026-04-23T09:35:46.3859554Z" distance="5.415" energy="11017.679" height="0.225" interval="0"/>
  <Blow date="2026-04-23T09:35:47.2095420Z" distance="5.484" energy="9674.171" height="0.197" interval="0"/>
  <Blow date="2026-04-23T09:35:47.9976058Z" distance="5.561" energy="7814.945" height="0.159" interval="0"/>
  <Blow date="2026-04-23T09:35:48.8256896Z" distance="5.634" energy="10200.997" height="0.208" interval="0"/>
  <Blow date="2026-04-23T09:35:49.6492753Z" distance="5.720" energy="12358.070" height="0.252" interval="0"/>
  <Blow date="2026-04-23T09:35:50.4738612Z" distance="5.806" energy="9251.716" height="0.189" interval="0"/>
  <Blow date="2026-04-23T09:35:51.3009497Z" distance="5.894" energy="10541.503" height="0.215" interval="0"/>
  <Blow date="2026-04-23T09:35:52.0639923Z" distance="5.982" energy="9454.328" height="0.193" interval="0"/>
  <Blow date="2026-04-23T09:35:52.8875814Z" distance="6.064" energy="10480.878" height="0.214" interval="0"/>
  <Blow date="2026-04-23T09:35:53.7161668Z" distance="6.140" energy="11303.942" height="0.230" interval="0"/>
  <Blow date="2026-04-23T09:35:54.5392521Z" distance="6.208" energy="10278.151" height="0.210" interval="0"/>
  <Blow date="2026-04-23T09:35:55.3668530Z" distance="6.272" energy="10509.132" height="0.214" interval="0"/>
  <Blow date="2026-04-23T09:35:56.1904371Z" distance="6.334" energy="10314.139" height="0.210" interval="0"/>
  <Blow date="2026-04-23T09:35:57.0140228Z" distance="6.388" energy="11224.197" height="0.229" interval="0"/>
  <Blow date="2026-04-23T09:35:57.8391087Z" distance="6.450" energy="11792.984" height="0.240" interval="0"/>
  <Blow date="2026-04-23T09:35:58.6531883Z" distance="6.501" energy="11315.832" height="0.231" interval="0"/>
  <Blow date="2026-04-23T09:35:59.4832779Z" distance="6.554" energy="9719.771" height="0.198" interval="0"/>
  <Blow date="2026-04-23T09:36:00.3063628Z" distance="6.611" energy="11236.559" height="0.229" interval="0"/>
  <Blow date="2026-04-23T09:36:01.1339518Z" distance="6.666" energy="11782.948" height="0.240" interval="0"/>
  <Blow date="2026-04-23T09:36:01.9610412Z" distance="6.721" energy="11492.989" height="0.234" interval="0"/>
  <Blow date="2026-04-23T09:36:02.7876272Z" distance="6.776" energy="10222.619" height="0.208" interval="0"/>
  <Blow date="2026-04-23T09:36:03.6147154Z" distance="6.830" energy="9106.554" height="0.186" interval="0"/>
  <Blow date="2026-04-23T09:36:04.4408026Z" distance="6.895" energy="9287.458" height="0.189" interval="0"/>
  <Blow date="2026-04-23T09:36:05.2688916Z" distance="6.954" energy="10736.887" height="0.219" interval="0"/>
  <Blow date="2026-04-23T09:36:06.0924774Z" distance="7.026" energy="9666.892" height="0.197" interval="0"/>
  <Blow date="2026-04-23T09:36:06.9150622Z" distance="7.092" energy="10493.657" height="0.214" interval="0"/>
  <Blow date="2026-04-23T09:36:07.7386476Z" distance="7.170" energy="11782.948" height="0.240" interval="0"/>
```

Conclusion

In conclusion, the measurement of hammer impact energy in driven piling operations is a critical component for ensuring installation quality, performance, and safety. Traditional approaches based on indirect estimations introduce significant uncertainty, as they do not account for real system losses or dynamic variations during driving. By incorporating a dedicated energy measurement system, such as the solution integrated with Trimble Groundworks machine control system, it becomes possible to obtain reliable, real-time data on hammer performance and energy delivery.

The use of proximity sensors, combined with appropriate calculation methods and calibrated correction factors, provides a practical and effective means of estimating impact energy directly on the rig. When properly installed and configured, this approach enables accurate blow detection, consistent monitoring, and improved alignment between field operations and design expectations. Ultimately, the integration of energy measurement technology enhances decision-making, reduces the risk of underdriving or overdriving, and contributes to more efficient and controlled piling operations.