The Universal Ledger: Conservation and the Equivalence of Work

The universe operates on a strict, unyielding accounting system. Energy cannot be created or destroyed, only transferred.

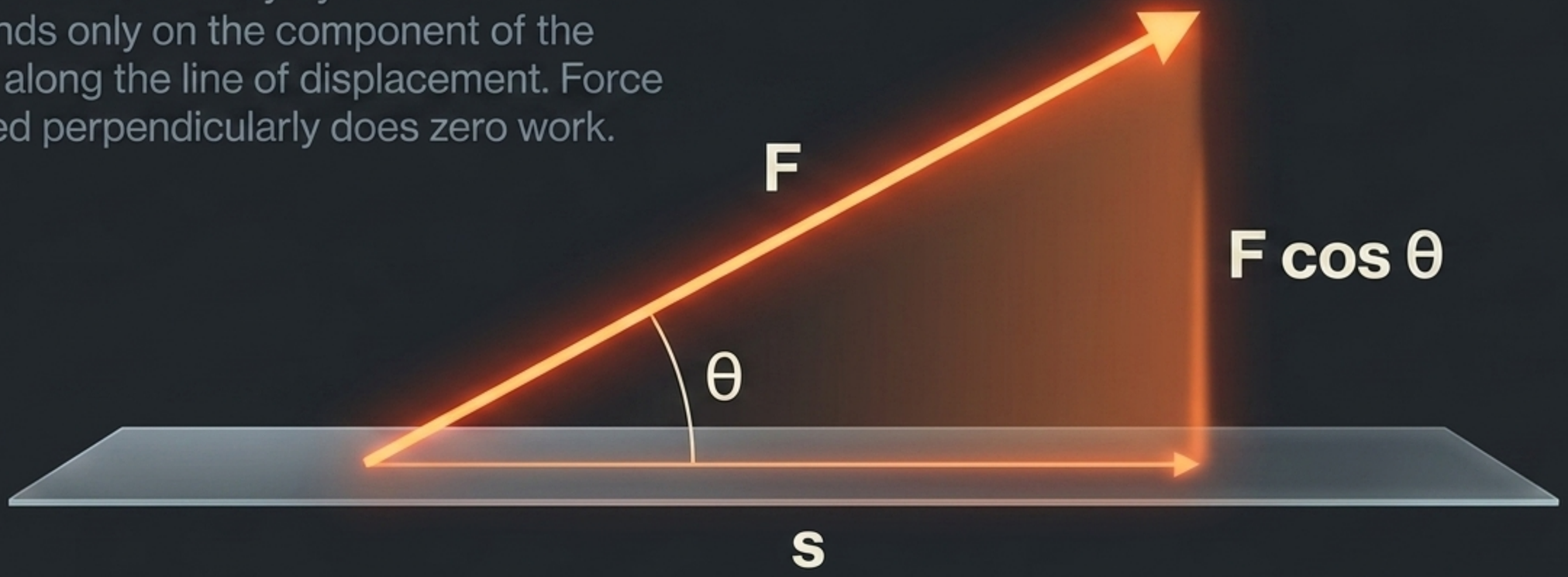
The principle of the conservation of energy.

Work done by the resultant force on a system is equal to the change in the energy of the system.

Work done by a force is equivalent to a transfer of energy.

Transfer Mechanics: Intentional Force and Displacement

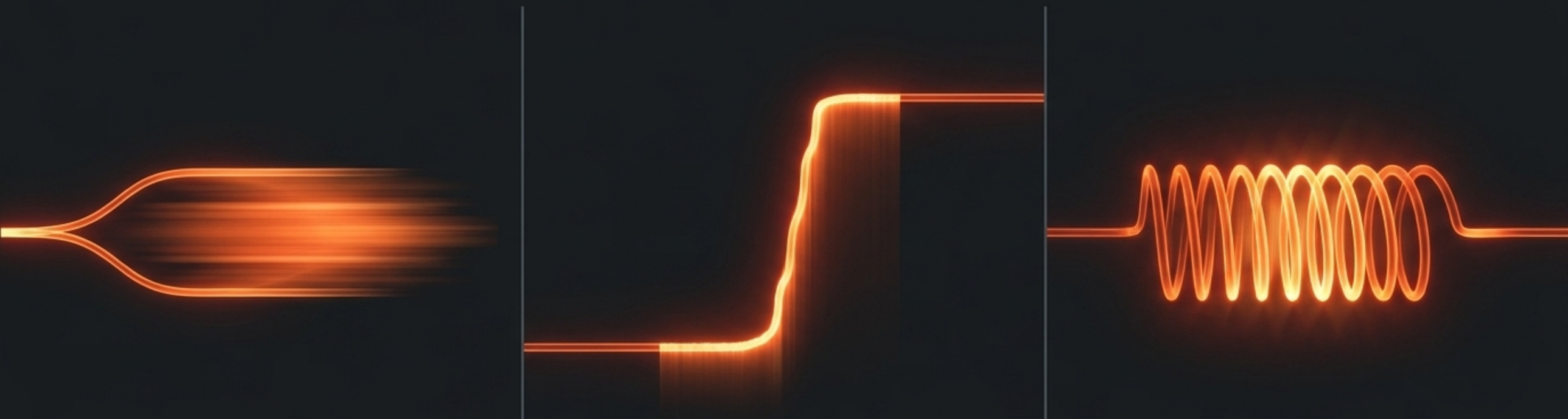
Work done on a body by a constant force depends only on the component of the force along the line of displacement. Force applied perpendicularly does zero work.



$$W = Fs \cos \theta$$

The Three Faces of Mechanical Energy

Mechanical energy is the sum of kinetic energy, gravitational potential energy and elastic potential energy.



Kinetic Energy

Energy of translational motion.

Gravitational Potential Energy

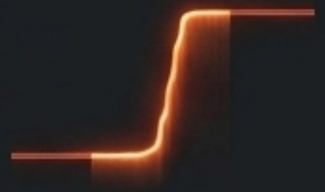
Energy of elevation close to the surface of the Earth.

Elastic Potential Energy

Energy of deformation.

Total Mechanical Energy = Kinetic + Gravitational Potential + Elastic Potential

Quantifying the States of Mechanical Energy

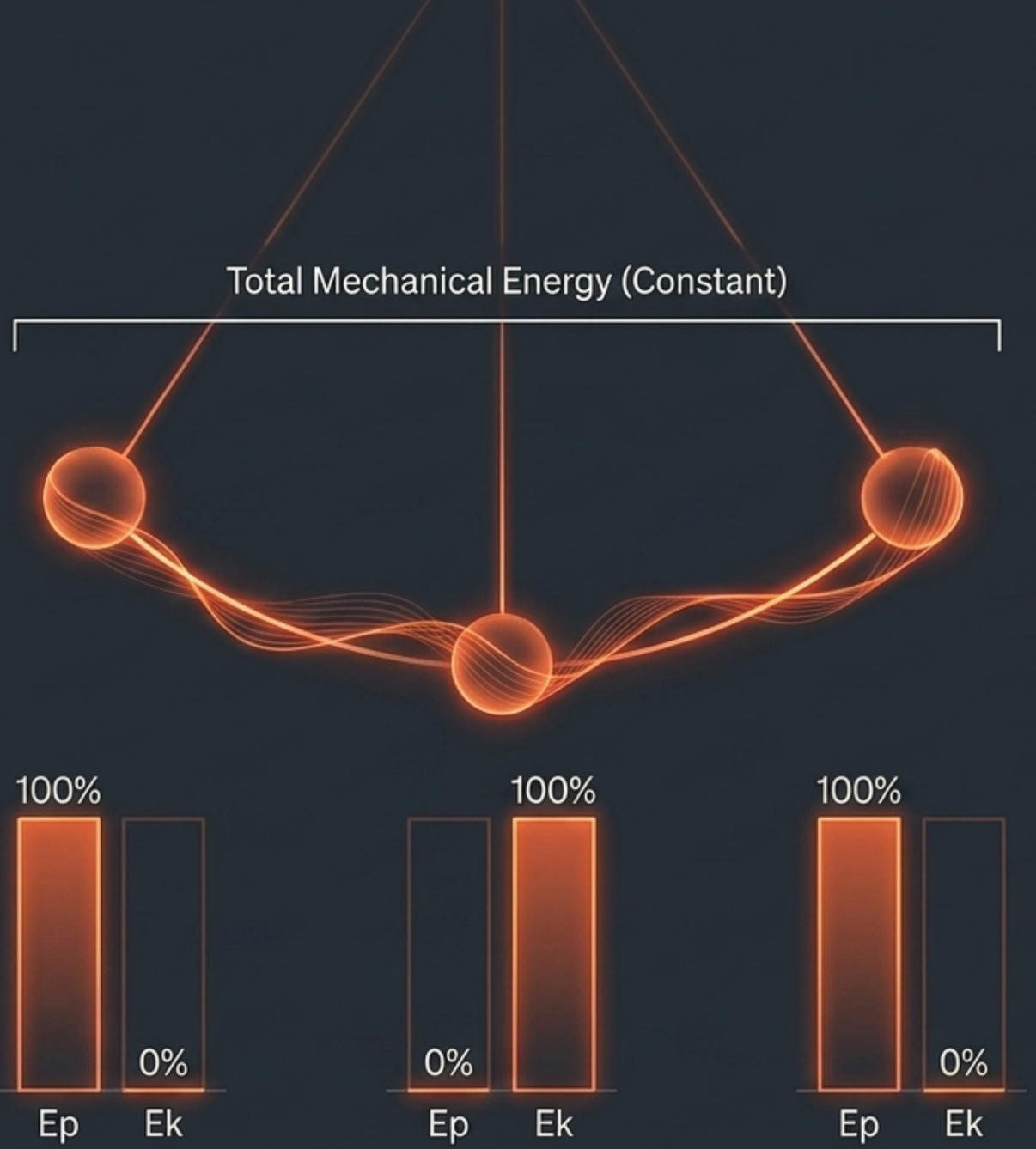


Kinetic Energy	Gravitational Potential	Elastic Potential
Trigger: Velocity / Motion	Trigger: Vertical Displacement	Trigger: Compression / Extension
$E_k = \frac{1}{2}mv^2$	$\Delta E_p = mg\Delta h$	$E_H = \frac{1}{2}k(\Delta x)^2$
$= \frac{p^2}{2m}$	—	—

The Ideal System: A Zero-Sum Dance

In the absence of frictional, resistive forces, the total mechanical energy of a system is conserved.

Work is simply the precise amount of energy transformed between different forms of mechanical energy within the system.



Introducing the Constraint of Time: Power

Moving a mountain one grain of sand at a time requires the same total Work as moving it all at once. The difference is Power.

Step 1

Power developed P is the rate of work done, or the rate of energy transfer.

Step 2 The Base Formula

$$P = \frac{\Delta W}{\Delta t}$$

Step 3 The Derivation

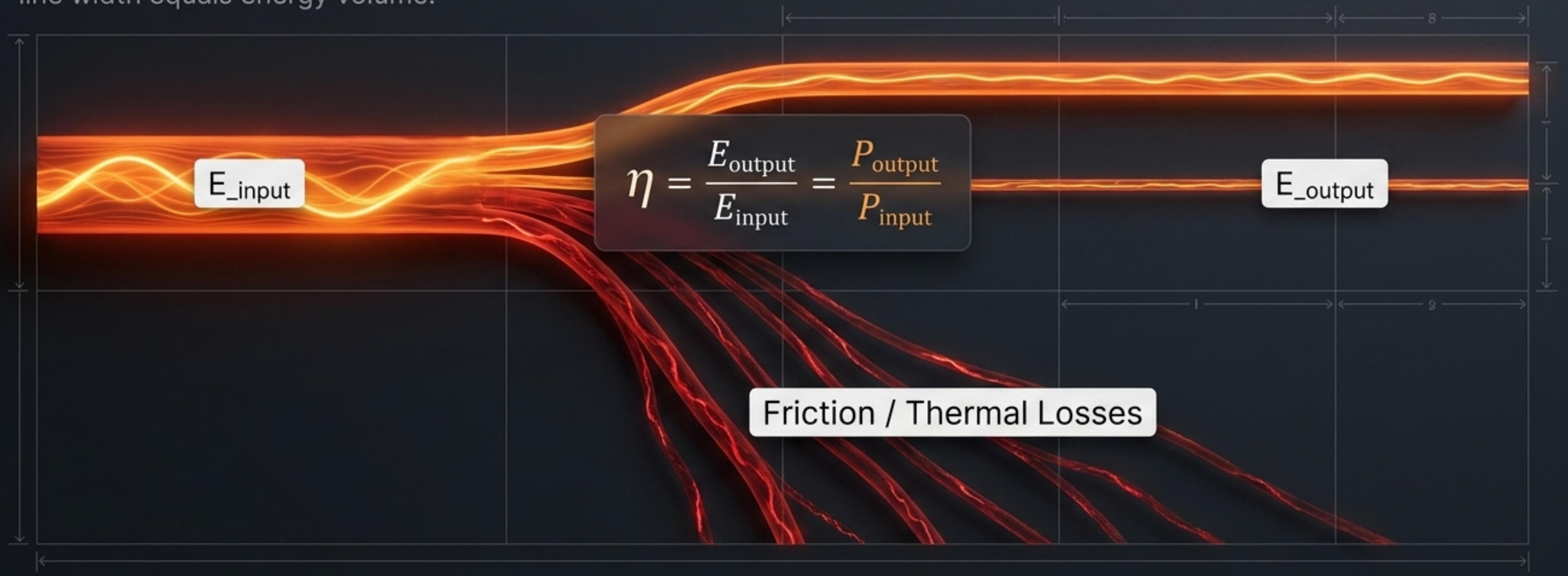
Since $\Delta W = F \cdot \Delta s$, then $P = F \cdot \left(\frac{\Delta s}{\Delta t}\right)$

Step 4 The Conclusion

$$P = Fv$$

The Cost of Reality: Efficiency and Thermal Bleed

Energy transfers in real systems are never perfect. Sankey diagrams visually map this reality, where line width equals energy volume.



The Physical Source: Fuel Energy Density

To combat real-world efficiency losses, engineered systems require dense, reliable physical sources to provide the input energy.

Energy density dictates the physical scale of human engineering. The higher the density of the fuel sources, the more potential work is locked within the same physical volume.