NESANS

PROCESS ENGINEERING & OPTIMIZATION

Bond's Work Index: Estimating Crushing Energy Before You Buy the Motor

Bond's Third Theory turns feed size, product size and work index into kWh/t. Work two examples and convert specific energy into an installed motor power.

Author: Sivabalan Selvarajan

Published: July 2, 2026

Reading Time: 7 minutes

Before you specify a crusher motor, you can estimate the energy the rock will demand — from a single number, the **work index**. Bond’s Third Theory of Comminution turns feed size, product size and rock hardness into kilowatt-hours per tonne, and from there into an installed power.

Getting that estimate before you specify the drive avoids two expensive errors: an undersized motor that stalls in hard rock, and an oversized one that runs lightly loaded and inefficiently for twenty years. We work the energy, see why fine products cost so much more than coarse ones, and convert the result into an installed power that ties straight back to the motor-sizing and cost-per-tonne articles in this series.

Bond's equation

The specific energy to reduce rock from F_{80} to P_{80} (both in microns) is

$$W = 10\,W_i\left(\frac{1}{\sqrt{P_{80}}} - \frac{1}{\sqrt{F_{80}}}\right) \quad \text{[kWh/t]}$$

where W_i is the work index of the rock. The form says something physical: energy scales with the new surface created, so making finer product (small P_{80}) costs disproportionately more.

SYMBOL	MEANING	UNITS
W	Specific energy required	kWh/t
W_i	Bond work index of the rock	kWh/t
F_{80}	Feed 80% passing size	micron
P_{80}	Product 80% passing size	micron

Worked example 1

Granite ($W_i = 15$) reduced from $F_{80} = 150{,}000\,\mu\text{m}$ (150 mm) to $P_{80} = 12{,}000\,\mu\text{m}$ (12 mm):

$$W = 10 \times 15\left(\frac{1}{\sqrt{12{,}000}} - \frac{1}{\sqrt{150{,}000}}\right) = 150\,(0.00913 - 0.00258) = 0.98\ \text{kWh/t}.$$

Why finer costs more

Figure 1 plots W against product size for three work indices. The curve steepens sharply toward fine sizes — the last few millimetres of reduction can cost as much energy as all the coarse crushing before it.

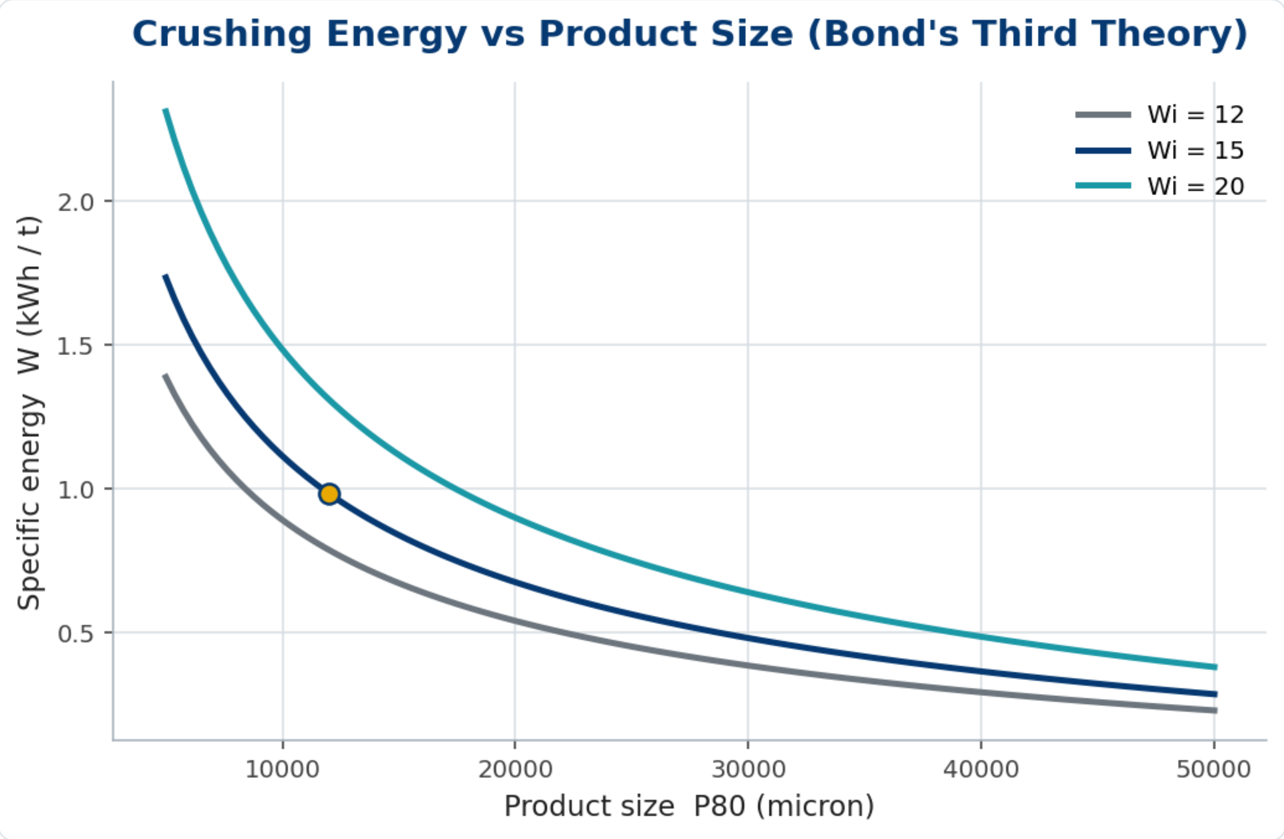

Figure 1. Specific energy versus product size. Finer products (left) cost disproportionately more — and harder rock (higher W_i) raises the whole curve.

Work index by rock

The work index is the rock's comminution 'hardness', from soft limestone to abrasive quartzite:

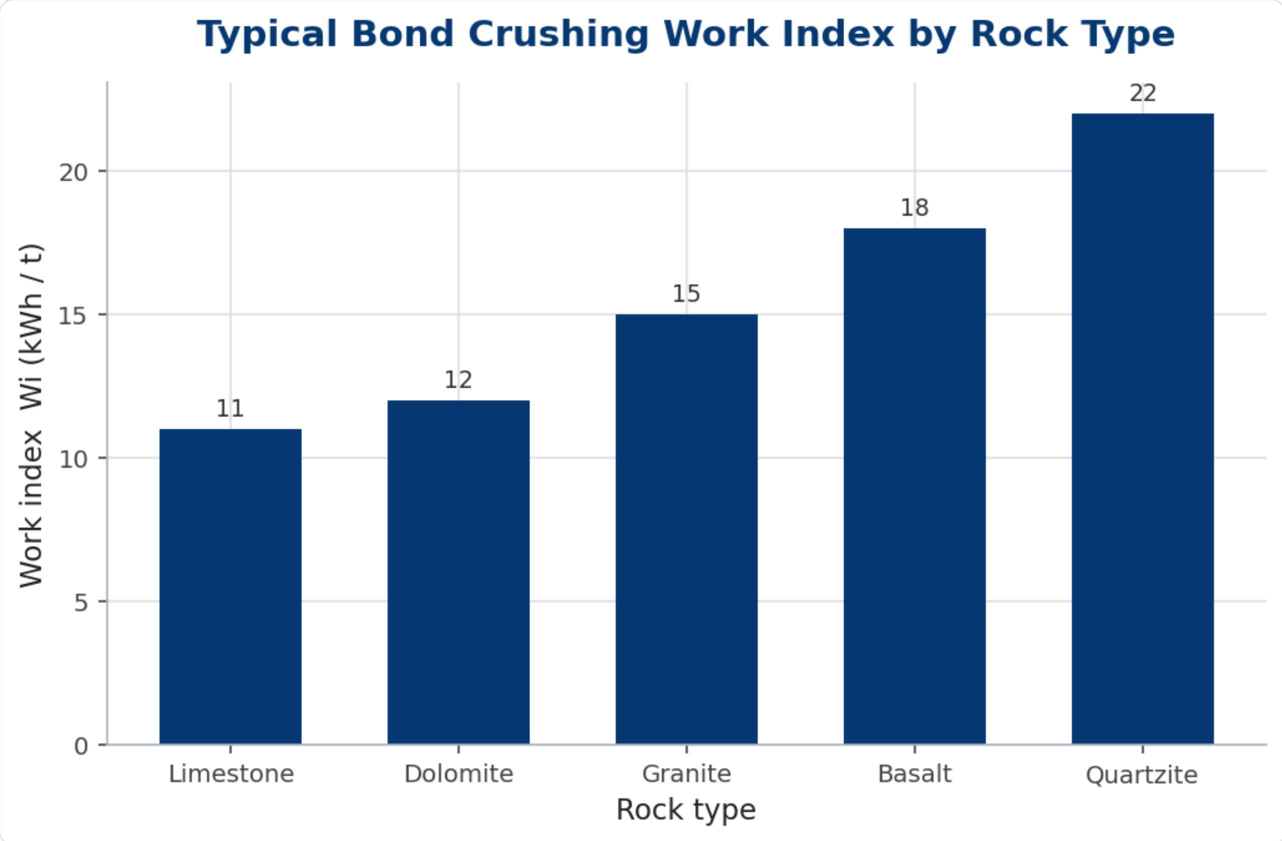

Figure 2. Typical crushing work indices. Doubling W_i doubles the energy — and usually the wear — for the same size reduction.

Worked example 2 — from energy to motor

At 200 t/h, the example duty needs $0.98 \times 200 = 196\,\text{kW}$ at the crushing zone. Allowing for drive and mechanical inefficiency (~75–80%), the installed motor is $196/0.78 \approx 250\,\text{kW}$ — which ties straight back to the specific-energy and cost-per-tonne figures in the companion articles.

> Use the right index. Bond's crushing work index applies to coarse comminution; rod- and ball-mill indices differ. Applying a grinding index to a crusher over-estimates energy badly.

Where the energy goes in the circuit

It is tempting to read Figure 1 as ‘the tertiary does all the work’. Apply Bond stage by stage and the truth is subtler. Taking the same granite from 150 mm to 12 mm through intermediate P_{80} of 40 and 20 mm:

STAGE	SIZE STEP (P80)	ENERGY W (KWH/T)
Primary	150 → 40 mm	0.36
Secondary	40 → 20 mm	0.31
Tertiary	20 → 12 mm	0.31
Total	150 → 12 mm	**0.98**

Across crushing, the energy is spread fairly evenly — even slightly front-loaded — because each stage roughly halves the size. The disproportionate cost of fineness only bites when you push toward grinding sizes (microns), where the $1/\sqrt{P_{80}}$ term runs away. The practical message for a crushing plant: no single stage is the energy villain, so size every motor to its own duty rather than over-powering the last one on a hunch.

In practice

The work index is as useful for selection as for energy. A high-W_i, abrasive rock argues for more crushing stages and tougher liner alloys, because forcing the reduction through too few stages spikes both energy and wear at once. Use a measured W_i where the contract is large enough to justify the test; otherwise anchor on a published value for the rock type and carry margin. And remember the index predicts average energy — the instantaneous power peaks on a tramp lump or a momentarily packed chamber are handled by drive sizing and protection relays, not by Bond’s law.

Common mistakes

- **Mixing indices.** Crushing, rod and ball work indices are not interchangeable.
- **Forgetting efficiency.** W is energy at the rock; the motor must be larger.

- **Extrapolating too far.** Bond’s law is an estimate, best within the size range it was calibrated for.

Frequently asked questions

What are F80 and P80?

The feed and product sizes through which 80% of the material passes — the standard basis for comminution energy.

How does Bond differ from Kick and Rittinger?

Kick scales energy with volume reduction, Rittinger with new surface; Bond’s square-root law sits between them and fits crushing/grinding data well.

Where do I get the work index?

A standard Bond test, or published values for the rock type as a first estimate before design.

Bond among the comminution laws — and its limits

Bond’s equation is one of three classical comminution laws, and knowing where each applies keeps it honest. Each describes how energy relates to size reduction, but over a different size range. Kick’s law holds for coarse crushing, where energy scales with the volume reduction ratio; Rittinger’s law holds for fine grinding, where energy scales with the new surface area created; and Bond’s law sits between them, scaling with the difference in the inverse square-roots of the sizes.

Bond’s middle ground is precisely why it is the workhorse for crushing and coarse milling: the feed and product sizes a quarry deals with fall squarely in its range. But it is an empirical correlation, not a law of physics, calibrated on particular tests — so it estimates rather than predicts, and it grows unreliable at the extremes, over-stating energy for very coarse crushing and under-describing very fine grinding.

The work index itself carries assumptions. It is measured by a standard laboratory test under defined conditions, and a real crusher’s efficiency differs from that test, so the same rock can show different effective work indices in the lab and in the plant. Treat the Bond estimate as a sound first approximation for motor sizing and energy budgeting — close enough to choose the drive — not as an exact prediction of the kilowatt-hours a particular machine will draw.

The practical stance, then, is to use Bond for what it is good at: a quick, rock-specific energy estimate to size motors and compare circuits in the crushing range, sanity-checked against measured plant power once running. Knowing it is the middle law of three, empirical and range-limited, is what stops a useful estimate from being mistaken for a precise answer.

The bottom line

Bond’s law is the cheapest engineering you can do before buying a crusher: a work index, two sizes, and you have an energy figure and an installed power that will not embarrass you. Used with a clear head — the right index, an efficiency allowance, the knowledge that it predicts averages — it anchors the whole drive and cost picture.

Read stage by stage it also dispels a myth: in crushing, energy is shared fairly evenly across the stages, and the runaway cost of fineness belongs to grinding. Size each motor to its own duty and you neither stall in hard rock nor pay for idle iron.

Key takeaways

- $W = 10W_i(1/\sqrt{P_{80}} - 1/\sqrt{F_{80}})$, sizes in micron.
- Energy scales with new surface — fine products cost disproportionately.
- Work index captures rock hardness; doubling it doubles energy and wear.
- Convert W to installed power by dividing by drive efficiency (~0.78).

Topics: #Bond Work Index #Comminution #Crushing #Energy

NESANS

www.nesansindia.in
SF No 20/1, Eachanary Madukkarai Road, Coimbatore, TN 641024
+91 9578 799 755