NREL Transforming ENERGY

A new manufacturing technique makes it easier, cleaner, and more cost effective to produce promising materials. *Image courtesy of Pacific Northwest National Laboratory*

Novel Manufacturing Method Could Reduce Costs, Time, and Energy Needed To Make High-Quality Metals

Industry is responsible for about 30% of U.S. carbon emissions and consumes about a third of the country's energy.[1] Much of that energy is used to make essential materials for transportation, defense, and marine applications, like cars, airplanes, space shuttles, and ships. Now, with a novel manufacturing method, called Shear Assisted Processing and Extrusion **(ShAPE), manufacturers could make higher quality materials while significantly reducing their energy consumption, carbon emissions, and costs.**

As part of the ShAPE research effort, performed with the Pacific Northwest National Laboratory (PNNL), researchers from the National Renewable Energy Laboratory (NREL) analyzed the economic value of this new manufacturing process and focused specifically on a promising high-strength, low-weight metal: aluminum alloy 7075 (an alloy made with about 90% aluminum, 6% zinc, and a few additional metals). Their results are published in the 2022 report titled *Techno-Economic Analysis for Shear Assisted Processing and Extrusion (ShAPE) of High-Strength Aluminum Alloys*. Although this material could help build lighter-weight and more efficient vehicles, it has been too costly, slow, and energy-intensive to make. With their analysis, NREL experts showed that ShAPE could help overcome these barriers and encourage widespread adoption of this valuable aluminum alloy.

What Is ShAPE?

To make metal rods or tubes used in parts for cars, airplanes, space shuttles, and more, manufacturers use a process called extrusion, which pushes metals through a mold. Metal extrusion often requires high heat (which can cause unwanted melting), large amounts of energy, and slow, time-consuming processes.

An alternative extrusion method, ShaPE, could be key to manufacturing with metals and alloys that have enhanced properties while reducing costs, power needs, and time. With funding from the U.S. Department of Energy's Advanced Manufacturing Office, NREL partnered with PNNL to analyze ShAPE.

While PNNL led the development, testing, and characterization of ShAPE, NREL researchers analyzed the economic and technological benefits of using the novel process in manufacturing. At the same time, NREL's experts explored how ShAPE could improve manufacturing components made out of aluminum alloy 7075.[2]

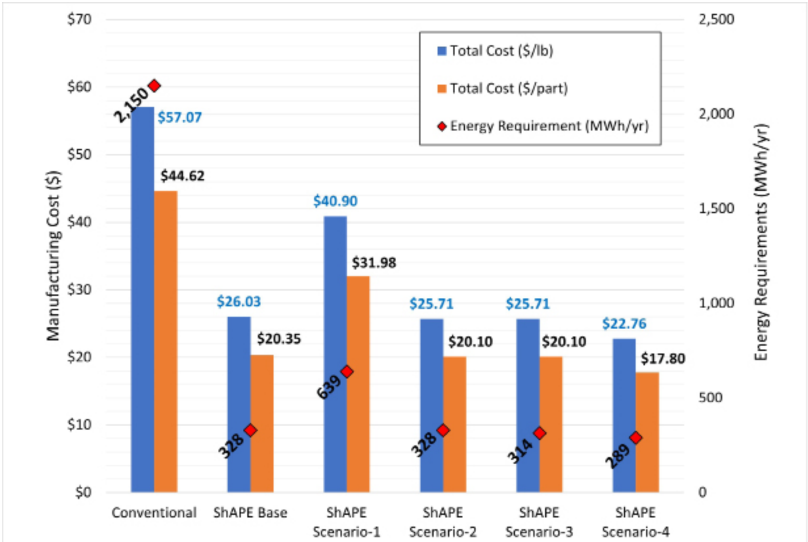
How Does ShAPE Compare to Conventional Methods?

To measure the cost and energy savings associated with ShAPE, NREL researchers built models and performed manufacturing analysis on hollow tubes made with the aluminum alloy 7075 using both conventional and ShAPE processes.

This comparison revealed that ShAPE can:

- Produce materials at least 5–6 times faster than conventional methods
- Cost at least 55% and up to 85% less than conventional extrusion methods
- Reduce energy consumption by at least 70% (and up to 76% with faster extrusion speeds)
- Prevent between 118 and 269 metric tons (t) of carbon dioxide emissions (equivalent to the annual emissions caused by between 26 and 58 passenger cars) per year (yr).

These large reductions in energy use and costs are primarily a result of ShAPE's speed and the elimination of ingot and billet thermal treatments prior to extrusion compared to conventional manufacturing methods.



ShAPE can significantly reduce manufacturing costs. ShAPE scenarios modeled in the analysis seen in the chart are described in the table and show the manufacturing cost and energy requirements for conventional extrusion as compared to various ShAPE scenarios, all of which use significantly less energy (in megawatt-hours [MWh]/yr) and cost about 28%–60% less per pound (lb) of material. *Images by Sertac Akar, NREL*

Model Specifications for Scenarios To Test the ShAPE Cost Model

	Conventional Extrusion	ShAPE (base case)	ShAPE Scenario-1	ShAPE Scenario-2	ShAPE Scenario-3	ShAPE Scenario-4
Manufacturing Volume	50 t/yr	50 t/yr	50 t/yr	50 t/yr	50 t/yr	50 t/yr
Homogenized Billets	Yes	Yes	Yes	No	No	No
Billet Cost	$5.46/kilograms (kg)	$5.46/kg	$5.46/kg	$4.91/kg	$4.91/kg	$4.91/kg
Part Diameter Inner/Outer	10/12 millimeters (mm)	10/12 mm	10/12 mm	10/12 mm	10/12 mm	10/12 mm
Final Product Length	6.01 meters (m)	6.01 m	6.01 m	6.01 m	6.01 m	6.01 m
Ram Speed	1 mm/second (s)	6 mm/s	1 mm/s	6 mm/s	6 mm/s	10 mm/s
Extrusion Speed	20 mm/s	117 mm/s	20 mm/s	117 mm/s	117 mm/s	195 mm/s
Billet Preheating	On	Off	Off	Off	Off	Off
Artificial Aging Time	24 hours (h)	24 h	24 h	24 h	10 h	24 h
Solution Heat Treatment	On (2 h)	On (1 h)	On (1 h)	On (1 h)	On (0.75 h)	Off

The details of these scenarios are provided in the *Techno-Economic Analysis for Shear Assisted Processing and Extrusion (ShAPE) of High-Strength Aluminum Alloys* report.

Who Can Benefit From This Work?

High-strength aluminum alloy 7075 is a valuable material for a wide range of applications, including equipment for transportation and defense, as well as rock climbing, bicycles, inline skates, and hang gliders. With ShAPE, it could be far more cost-effective to build these products.

Further validation of the ShAPE model through physical production in manufacturing facilities requires industry partnerships. At the same time, NREL researchers plan to extend their economic and technological analyses to assess how the method could be applied to:

- Other manufacturing feedstocks (like aluminum alloy 7075 power instead of billets)
- The production of different aluminum alloys
- Different machine sizes.

These critical analyses can help build the next generation of the ShAPE machine.

For more information about this research, contact: **Sertac Akar,** Sertac.Akar@nrel.gov.

This fact sheet summarizes the information found in the following report and references therein:

Sertac Akar, Christopher Kinchin, and Parthiv Kurup. 2022. *Techno-Economic Analysis for Shear Assisted Processing and Extrusion (ShAPE) of High-Strength Aluminum Alloys*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-80038. https://www.nrel.gov/docs/fy22osti/80038.pdf.

[1] U.S. Energy Information Administration. 2021. *Annual Energy Outlook 2021*. Washington, D.C.: U.S. Department of Energy. AEO2021 Narrative. https://www.eia.gov/outlooks/aeo/pdf/AEO_Narrative_2021.pdf.

[2] Wang, T., J. Atehortua, M. Song, Md. Reza-E-Rabby, B.S. Taysom, J. Silverstein, T. Roosendaal, D. Herling, and S. Whalen. 2022. "Extrusion of Unhomogenized Castings of 7075 Aluminum via ShAPE." *Materials and Design* 213: 110374. https://doi.org/10.1016/j.matdes.2021.110374.

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