Layer by layer, inch my inch, the world's first 3-D printed vehicle seemingly emerged from thin air this week on the floor of the International Manufacturing Technology Show in Chicago.

The Strati, named after the Italian word for layer, was printed in one piece over 44 hours using a process called direct digital manufacturing—the seamless fabrication of components from computer design to physical object. This is the first time this method has been used to make a car, one that also happens to be fully electric.

Mechanical components of the vehicle, including the battery, motor and suspension, were obtained from various sources, such as Renault's urban electric car Twizy. A team of engineers will rapidly assemble the final parts of the vehicle today and, if all goes well, will take it on a historic first test drive tomorrow.

The project is being spearheaded by Local Motors, a self-styled vehicle innovation company based in Arizona. According to CEO John Rogers, the Strati marks a breakthrough in automotive history by proving that a car can be created in an entirely new way.

"Our whole bet has been for the military or average civilian consumers or for fleet customers, that if you can change the way you make a vehicle, and do it faster, then you can catch innovation as it comes along more quickly," he said.

The Strati, considered a two-seater "neighborhood" electric vehicle, has a range of 100 to 120 miles (depending on the battery pack) and a maximum speed of 40 mph. Because it's not designed for highways, the Strati can be licensed without having to pass all of the standard safety tests. Local Motors plans to start selling production-level cars before the end of the year for

between $18,000 and $30,000.

But perhaps more novel than the Strati itself is the way in which it was made. Rapid, local, flexible manufacturing could have broad economic, societal and environmental implications.

Local Motors, best known for making the Rally Fighter off-highway vehicle, has come a long way in a short period of time. When Local Motors signed a partnership agreement with the Department of Energy's Oak Ridge National Laboratory in January, it didn't have a printing machine, it didn't have printing material and it didn't have a design for the car.

All of those tasks were completed in just six months. The company started printing in the last three months and has already gone from more than 140 hours of printing time to complete a car to less than 45 hours as of this week.

"We expect in the next couple of months to be below 24 hours and then eventually get it below 10 hours," Rogers said. "This is in a matter of months. Today, the best Detroit or Germany can do is 10 hours on a [production] line, after hundreds of years of progress."

Local Motors' mission is to manufacture faster, but also more democratically. Mass manufacturing concentrates jobs and revenue in specific areas, whereas 3-D printing can give any city or even individual home the ability to create. In terms of vehicles, that means a community with vast supplies of natural gas might decide to build a natural gas-powered vehicle, a community with access to hydrogen might decide to build a hydrogen-powered vehicle or a community with a clean electricity mix might decide to build an electric vehicle.

For Rogers, the ability to make locally is the ability to innovate locally. These innovations could then work their way up the production chain to reach a mass scale.

"In the future, you'll still have ... your Detroits that make one product the same over a million units," he said. "And then I think you'll have examples of microfactories that do things profitably at lower volumes—10,000 units, 15,000 units per year—and show the mass factories what they ought to build next."

The flexibility of the 3-D printing process makes it cost-effective relative to conventional manufacturing in low volumes. Large-scale production involves high startup costs for making molds and tooling, but once the process is started, the per-unit cost is very low, whereas the cost per unit of a 3-D printed product is higher, but the product can be prototyped and redesigned within a few days for just the cost of materials. This makes it easy to create customized products.

The design for the Strati, for instance, was selected from more than 200 entries submitted by Local Motors' online community. Local Motors decided to go with an electric powertrain because it has fewer parts and so is relatively simple to construct.

The open-source platform is the core of Local Motors' projects. Meanwhile, other automakers have only just started to embrace the concept.

Speed, not patents, winsRogers said that when he met with Elon Musk seven years ago, the CEO of Tesla Motors Inc. told him that Local Motors' open-source approach would never succeed because engineers don't like working together. In an apparent change of course, Tesla Motors announced in June that it would make all of its patents publicly available.

"I think we're the biggest part of that," said Rogers. "We have been pushing the industry to say the advantage for everyone is the speed of manufacturing, not protectionism. I'm glad to see Elon has figured that out."

Tesla's decision to release its intellectual property "is an incredible opportunity to show the world that leaders in technology believe in not holding down innovators, but empowering them to stand on each other shoulders and move faster," he added. "That is a huge deal. And it's showing the patent system you're not the right way to innovate."

In March, General Electric Co. announced a partnership with Local Motors to build and commercialize next-generation GE products using Local Motors' First Build open-source platform. GE is also a strong supporter of 3-D printing, with more than 300 printers currently in use across the company.

Last year, GE and the open engineering community GrabCAD launched a global 3-D printing challenge to design a jet engine bracket. The winner, M Arie Kurniawan, an engineer from Central Java, Indonesia, came up with a design that was 30 percent lighter while preserving the part's integrity and mechanical properties.

The ability to make complex shapes using fewer parts and less material without sacrificing strength is one of the main benefits of 3-D printing, said Anthony Vicari, a research associate at Lux Research and author of a recent 3-D printing market report. Lighter-weight designs also have direct energy-saving benefits for the aerospace and automotive industries in terms of reduced fuel burn.

More energy, less wasteHowever, fusing a plastic or metal

powder for 3-D printing requires a lot of energy.

"If you're using a 100-watt laser for several hours to make a part, or if you're heating your build chamber to the melting point of plastic for several hours overnight, that's a very energy-intensive production process," said Vicari in an interview earlier this year. "If you just looked at that specific step, you wouldn't see energy savings."

"Like so many things in climate and energy, you have to do a life cycle analysis for each part to get a real accurate answer," he added.

Part of what makes understanding the environmental aspects of 3-D printing so complicated is that there are so many different types of printing technologies and printing materials, said Robert Olson, a senior fellow at the Institute for Alternative Futures, based in Alexandria, Va. Some can use hundreds of times more energy than conventional manufacturing processes, he said.

The Strati was made from thermoplastic using a Big Area Additive Manufacturing (BAAM) machine. While the process is energy-intensive, it has the separate environmental benefit of being fully recyclable. For the material to be reused, it simply has to be chopped up and reprocessed back into another car. Steel and aluminum cars can also be recycled, but removing the glues and paints during the deconstruction process is more complex and time-consuming.

Some 3-D printing processes also waste less material than conventional manufacturing during the building process. But Olson said that that's not true for all types.

He also said it's unclear whether the distributed manufacturing

model would be better or worse in terms of energy use.

"Claims have been made that 3-D printing can really save transportation energy, because if you manufacture things near where they're going to be used and you don't have to ship them," said Olson. "But on the other hand ... you'll be shipping machines all over the place and the materials used all over the place instead of just to a more central manufacturing facility."

"It's just not so clear-cut," he said. "People just haven't done careful analysis to see if these claims hold up over time."