**Background**

Connora’s technology stems from applying a novel chemistry approach to make materials more recyclable or removable. The original technology was inspired by chemistry commonly used in semiconductor photoresists and drug delivery. We applied this same chemistry to thermoset materials and found that there was an opportunity to do something that had never been done before; that is to make a performance thermoset resin (commonly used in expensive carbon fiber composites) truly recyclable.

**The Problem**

The trend for increased structural and mechanical performance of vehicles with better energy efficiency is leading the transportation industry to rely on lightweight, thermoset composite materials. Following Boeing’s ‘Dreamliner’ success story in aerospace, the automotive industry has also looked to thermoset composites as alternatives to aluminum, as it has faced continued pressure to improve fuel economy and lower carbon-dioxide (CO₂) emissions. Meanwhile, high carbon fiber costs have driven innovation in rapid production techniques, like HP-RTM (high pressure resin transfer molding) and carbon fiber recycling. Additionally, the EU ELV Directive targeted for 2015, requires 85% re-usable or recyclable materials by weight, with an additional allowance of 10% for incineration and energy recovery. So, even if with a high performance-to-weight ratio, the limited recyclability of composite materials could slow their adoption in volume production. To help composite manufacturers improve costs and meet regulatory compliance, Connora Technologies pioneered a novel chemical approach for creating and recycling epoxy thermoset composites. Epoxy resins are the predominant thermoset plastic used in performance carbon fiber composites today.

**The Opportunity**

Thermosetting plastics used today are not recyclable simply because they were never designed to be in the first place. Yet, there is nothing inherent about the design of thermosets that precludes them from being re-designed to be recyclable or reusable materials. Employing a chemical approach, Connora has developed a series of high
performance epoxy curing agents, called Recyclamines®, for the creation of inherently recyclable thermoset composites. These hardeners work with any di-epoxide molecule and are suitable for use with typical composite processing methods. Recyclamines® enable manufacturers and recyclers to readily extract value from composite waste. As light-weighting efforts in transportation and energy drive growth in the use of composites, these industries will likewise need efficient solutions for recycling post-manufacturing and end-of-life waste for both economic and regulatory reasons.

The Recycling Committee of the American Composites Manufacturers Association (ACMA), surveyed its member companies and claims that 5-10% of their production volume went to scrap. Based on the approximately $30 billion projection of the Global Composites Market for the year 2017 and the conservative estimate of 5%, production scrap alone constitutes $1.5 billion in lost revenue, withstanding the environmental impact. Over 70% of surveyed companies contributed manufacturing scrap to trim-offs and about 95% marked reject parts as their source of post-production scrap. Almost 80% of participating companies stated that absolutely none of their scrap, manufacturing or post-production, is ever recycled. 90% of these companies stated that their company sends the scrap to landfills. 100% of all companies who took the survey said that they would be interested in a recycling program where they could reuse their own scrap or outsource recycling to another company.

**The Technology**

The conceptual design of our recyclable epoxy thermoset is derived from our molecules, with a central ‘programmed cleavage’ group. Placement and stoichiometry of the engineered cleavable cross-links in the resulting plastic plays a direct role in recycling the thermoset into a well-defined thermoplastic. The low energy conditions required to quickly induce crosslink cleavage in the epoxy are a combination of temperature (70-100 °C) and pH (acidic). We have designed a high level of recycling control into our molecules, which give them excellent environmental weathering properties while still being recyclable under specific recycling solution and temperature. The mildness of the recycling approach is further highlighted by the high quality of recovered carbon fiber from our approach. We have found that there is no loss of physical properties, in both tensile modulus and the tensile strength, of the recycled carbon fiber versus virgin carbon fiber.

Our Recyclamines are physically on par or better than commercial curing agents of similar structures. We have pioneered new chemistries for making unique thermoset polymers. Molecular structures were iteratively created and evaluated for physical and mechanical properties in cured epoxy thermosets and composites. Lastly, we have demonstrated a fundamental understanding and high level of control during the recycling process (kinetics) and the post-recycled thermoplastic material.

**Market Applications**

The ‘beachhead’ target market for Connora is high-volume composite manufacturing,
where recyclability provides economic value to manufacturers due to the large amount of waste generated. Additionally, auto makers are pioneering more automated carbon fiber processing techniques to make composites. The global auto composites market alone represents an estimated $4B by 2017, with 7% Compound Annual Growth Rate (CAGR). A single, small volume, composite car model represents roughly ~400 metric tons (MT) Recyclamine, or $4-5M annual revenue, based on commercial systems. For this proposal, Connora is focused on developing novel materials and proving the technology in vehicle light-weighting applications due to the high performance requirements, fast market growth, and the validated need for recycling. However, our Recyclamine technology, in general, does have wider applications from sporting goods and consumer electronics, to energy, lubricants and additives.

**How Connora can change the System**

Based on the current market value of reclaimed carbon fiber and copper, the ability to reclaim and reuse high value materials from composites waste has the potential for significant cost savings to manufacturers of composites. Additionally, similar to the $60+B thermoplastic industry today, the creation of a secondary market for reclaimed composite materials also has significant market potential.

To produce Recyclamine, Connora has also developed a cost effective and industrially relevant platform different from how other amines are manufactured today. This proprietary platform would be of value to any large chemical company interested in participating in the large and growing amines market. This platform can be further leveraged to create an entire suite of polymers and materials outside of thermostet resins. Connora has a strong intellectual property portfolio in this application, as well as in the synthesis, design, and manufacturing of these molecules.

**What will enable our success**

The chemicals industry is dominated by large companies that make the incumbent, non-recyclable thermostet materials. Although these companies may understand Connora’s recycling value proposition, it may not be in their best interest to support our recycling agenda. Likewise, Connora, as a smaller chemical startup, needs access to manufacturing infrastructure usually limited to these large global chemical manufacturers. Access to such manufacturing resources will enable Connora to deliver our technology at industrial economies of scale and compete with current commercial materials.

Composites recycling will also require 3rd party recyclers that are motivated to help us bring this solution to the market. Connora will need the appropriate financial support to tackle the long term market transformation of both manufacturers and customers to adopt a new recycling solution. Aside from reaching out to traditional venture capital, we are seeking grants to help fund early R&D projects. Therefore, Connora is asking the help of influential individuals and organizations who share our vision and passion to make better materials for tomorrow’s composite materials.