GraphAir Impact Assessment

GraphAir – A novel form of graphene, with potential for use in membrane technology

Differentiators vs traditional solutions

- Greater efficiency and effectiveness
- Longer lasting (6X)
- Cost-effective (3X)

Role of SIEF EDP

- advanced GraphAir for commercial applications (TRL 3 to 6)
- steered focus on the end-use applications, future impact pathway identification and partner identification
- addressed significant funding gap
- provided valuable feedback from industry-focused review panel

Key Stakeholders

- Industry (various)
- Government and community
- SIEF and CSIRO

CBA: Investment and Benefits

Use Case: Type 2 Pure laboratory water purification equipment market
Pathway: Licence for royalties
Estimated Investment: $ 15 million
Project Case Benefits:
BCR: 1.5
NPV: $ 7.8 million

Prospective Benefits

- New revenue/ income
  New markets and supply chains
- ↓ environmental footprint of wastewaters.
- Improved health and wellbeing of rural communities

Impact Risks

- Lack of funding for scale-up.
- Technology failure at commercial scales
- Highly conservative, regulated, and mature nature of the water market

Current Scenario

- **Focus:** Type 2 high-purity water and brine treatment
- **Adoption:** None to date, further R&D required
- **Commercial partner:** TBD

Impact Assessment

- **Approach:** Mixed methods approach (Quantitative and Qualitative)
- **Confidence rating in assessment:** Very low

Engagement Opportunity

- **TRL:** 6
- **Pathways:** Investment/ JV/ Partnership
- **Contact:** Katie Green

Background

GraphAir is CSIRO's patented form of graphene, which can be used as a novel membrane technology. This technology is a long-lasting, high-flux water purification membrane capable of producing ultra-high purity water through a membrane distillation (**MD**) mode of filtration.

Industry Challenge & CSIRO's Response (claims)

- **High purity and ultrapure water purification process for laboratory applications:** High purity and ultrapure water are usually manufactured through a succession of 6 to 10 steps to meet the stringent purity requirements. GraphAir's initial proof-of-concept data demonstrates that it can generate Type 1 and 2 Pure laboratory water in 1-2 steps, thereby obviating the need for a complex multi-step process.
- **Filtration capabilities:** Unlike regular water filters, GraphAir can filter out extremely toxic chemical compounds while allowing only pure water through. It has narrow channels through which smaller water molecules can pass while blocking larger dissolved molecules and solvated ions. It can remove dissolved NaCl, metal salts, detergents, mineral oils, acids, alkalines, mine tailings, and per-/poly-fluoroalkyl (**PFAs**) chemicals from water.
- **Membrane fouling, ageing and disintegration:** GraphAir has been shown to last at least six times as long as conventional MD membranes (in accelerated ageing tests, 144 hours versus 24 hours) owing to its inherent anti-fouling properties. It provides an anti-scaling, long-lasting and high-flux graphene membrane.
- **Costs:** It is estimated to produce commercially relevant volumes of ultrapure water at an absorbed cost of $0.13/L compared to $0.37 /L for existing technologies.
- **Ability to produce pure water from hard-to-treat waters:** The membrane has been shown to produce pure water from complex mixtures, where most existing technologies fail or are exorbitantly expensive. The technology has been claimed to be economically viable. The purification process is thermally driven, instead of the usual pressure-driven mechanism common in Reverse Osmosis (RO), due to which it offers the potential of utilising solar and/or waste heat sources to further reduce the cost of operation.

GraphAir Developmental Journey

Pre-Science and Industry Endowment Fund Experimental Development Program (SIEF EDP)

CSIRO began the development of graphene sheet technology in 2015 and graphene water membrane in 2017. During this time, the team demonstrated the ability to produce 0.5 L/day of pure water from 10 cm^2 of the membrane at a laboratory scale.

SIEF EDP

The SIEF EDP grant between November 2019 and June 2022 advanced the GraphAir research for high and ultra-purity laboratory water market use case applications. It assisted in achieving four key aspects, highlighted in Figure 1 below.

Current Scenario

Post-SIEF EDP, the R&D team is seeking a partnership with a suitable commercial entity to support the development of a large-scale pilot system for field trials.

Impact Assessment Approach

This evaluation is based mainly on the impact hypothesis developed post-discussion with the core R&D team. Existing studies, research papers, market assessment report and SIEF submissions were reviewed. Due to the early-stage nature of this work, external stakeholders could not be consulted for the evaluation.

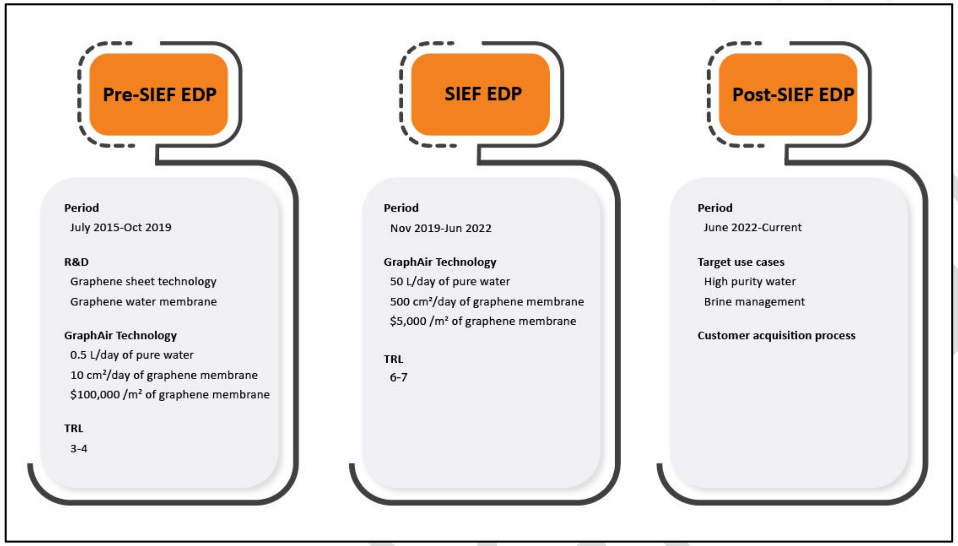

Figure 1: GraphAir technology development timeline.

Impact Hypothesis

GraphAir membrane distillation will be commercialised and adopted by industry to produce ultrapure and high-purity water using a significantly more efficient, effective, and cost-effective process.

Impact Pathway

The assessment adopted CSIRO's Impact Framework to identify the causal relationship of the initiative. Prospective benefits are estimated using a mixed-methods approach, i.e., quantitative (Cost Benefit Analysis – CBA) and qualitative analyses. Although an initial use case for GraphAir has not been finalised yet, the **CBA has been conducted based on its adoption in the Type 2 Pure laboratory water purification equipment market**. This use case was chosen based on the R&D team's suggestion that it is an optimum embodiment of technology for a commercially attractive solution (market segment globally growing at 8% Compound Annual Growth Rate (CAGR)), and the Technology Readiness Level (**TRL**) of GraphAir currently is the most advanced for this application.

Prospective Impacts

GraphAir's technical and commercial viability for real-world use cases is yet to be validated. However, there are compelling hypotheses for future impact potential in the form of economic-social-environmental benefits based on the evidence presented in the assessment.

CBA was performed based on the projected commercialisation through the licence for royalties pathway. This is expected to deliver benefit streams in the form of new royalty income for CSIRO from the sale of the licence and licensee benefits from the improved process enabled by the deployment of GraphAir.

CBA, based on conservative assumptions, estimates that successful deployment of GraphAir technology for commercial application by FY2028, it is anticipated to deliver a Benefit Cost Ratio (BCR) of 1.5 during the assessment period of 10 years (FY2028-FY2037). The Net Present Value (NPV) of benefits during this period is estimated at $7.8 million. The SIEF investment is expected to deliver a BCR of 2.4 and an NPV of $3.3 million during this period. Overall investment in research is estimated to be ~15 million.

The initiative is also expected to deliver other economic benefits in the form of new jobs, new markets and supply chains and provide improved support to industry (e.g. Hydrogen industry) etc. Deployment of technology is expected to reduce the environmental footprint of damaging wastewaters. On social impacts front, it is expected to enhance health and wellbeing of rural communities (e.g., from the improved provision of water in remote and arid areas of Australia, imparted by the technology) as well as grow innovation and human capital and develop higher skilled workforce.

Impact Risks

- Lack of access to financial support for system scale-up. Inability to secure the optimum commercial partner/ choose the most appropriate commercial use case.
- Technology failure at commercial scales due to technical and economic factors.
- High quantum of investment requirements for scale-up and a highly conservative, regulated, and mature nature of the water market, combined with a low-risk appetite of prospective commercialisation partners to adopt disruptive GraphAir technology.

SIEF's Role

The core R&D team noted that SIEF played an instrumental role in addressing the 'valley of death' phase (TRL levels 3-7), gaining commercial traction, and improving the impact potential of GraphAir technology. Key ways in which the EDP was particularly helpful included:

- making a concerted and focused effort possible on product/technology development.
- designing an EDP that drives the focus on the end-use applications, future impact pathway identification or partner identification as part of the technology development.
- filling a significant funding gap in the pathway of TRL and CRL progression of GraphAir technology without diluting the IP.
- providing valuable feedback from independent, industry-focused panel and support of the SIEF Secretariat.

Conclusions

The GraphAir initiative is aspirational and theoretically offers significant applications in several industry use cases. Although Type 2 high-purity water and brine treatment are focus spaces at this stage, the likely first use case is not locked-in yet. The next phase of funding support will be a major determinant in the pathway to TRL and IRL progression and delivery of impacts. The projection of benefits in this assessment is based on several assumptions that have not yet been substantiated by any commercial announcements and involve longer-term time frames. Accordingly, the confidence rating in this impact assessment is rated <u>very low</u>. This impact assessment provides a significant blueprint for future impact management for the GraphAir initiative. If, and as, GraphAir research progresses (technology, investment and commercialisation readiness levels) and there is an opportunity to consult external stakeholders (potential initial and end-users), the current study should be revisited and refined, drawing on more detailed evidence to provide improved insights.