

## AI-Driven GIS-LCA for Decarbonisation Decision Intelligence

Identifying hotspots, prioritising mitigation, and optimising interventions across Irish industrial supply networks

Sustain-FIT Call 2 • Host: University College Dublin • Co-mentor: Prof. Nick Holden (UCD) • Fellow: Dr. Guangcan Su

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### Why now — the Irish context

Irish firms face an unprecedented convergence of sustainability pressures. Ireland is currently projected to exceed both Carbon Budget 1 (2021-2025) and Carbon Budget 2 (2026-2030) under the Climate Action Plan 2025. At the same time, the **EU CSRD** has been transposed into Irish law, the **CBAM definitive phase began on 1 January 2026**, and 112 Irish stationary installations now report verified emissions under the EU ETS. Customers, investors and regulators increasingly demand **product-level, spatially resolved, audit-ready** evidence of action — not corporate averages.

Yet most Irish enterprises still rely on static, average-based carbon accounting that cannot answer the three questions sustainability teams are actually being asked: “Where are our real hotspots? Which interventions should we prioritise? *How do we know they will work here, not just in a generic benchmark?*”

### What we are building

A **decision-intelligence framework** that combines **Artificial Intelligence, Geographic Information Systems (GIS)** and **Life Cycle Assessment (LCA)** into a single workflow tailored to each partner enterprise. The framework ingests the firm’s own operational and ERP data (e.g. bill-of-materials, routings, plant and supplier records, logistics flows) together with a bounded set of company inputs, and delivers:

- **Spatially explicit, multi-impact LCA models** — climate change, acidification, land use and water use linked to the actual plants, suppliers, catchments and transport routes involved, rather than national-average factors.
- **AI-driven hotspot detection** — data fusion across operations, geography and logistics to surface where environmental burdens truly concentrate.
- **Ranked mitigation portfolios** — interventions ordered by emissions-reduction potential, indicative cost and implementation feasibility under real supply-network constraints.

- **Audit-ready decision summaries** — ISO 14040/14044/14067-aligned outputs suitable for CSRD, CBAM, EU ETS and customer-facing EPD reporting.

### Who this is for — Irish sectors where the framework fits

The methodology is sector-agnostic by design. Priority Irish sectors — each facing a structurally similar “where and which” decision problem — include:

- **Dairy & agri-food processing** — farm-gate Scope 3, SBTi-validated carbon-intensity targets, on-farm heterogeneity, water-quality and biodiversity trade-offs. Example companies: Tirlán, Kerry Dairy Ireland, Ornuu, Dairygold, Lakeland Dairies, Aurivo, Carbery, ABP Food Group.
- **Beverages & distilling** — sustainable grain sourcing, malting/brewing/distilling energy use, net-zero direct operations by 2030-2040. Examples: Diageo Ireland, Irish Distillers (Pernod Ricard), C&C Group, Heineken Ireland, William Grant & Sons.
- **Pharma & medtech** — supplier-API Scope 3, ISO 14067 product carbon footprints for device families, reprocessing-LCAs, renewable-electricity siting. Examples: Stryker, Boston Scientific, Alkermes, Chanelle Pharma, APC, Pfizer, MSD, Johnson & Johnson.
- **Semiconductor & electronics** — deep Scope 3 value chains, temporal-spatial matching of renewable PPAs, grid-carbon intensity of Irish operations. Examples: Analog Devices (Limerick), Intel Ireland (Leixlip), and Tyndall-affiliated SMEs.
- **Cement, construction materials & building products** — Ireland’s 30% clinker-substitution mandate for public-works concrete, EPDs, CBAM-embedded emissions in cement/steel/aluminium inputs. Examples: CRH, Irish Cement, Ecocem, Kingspan, Saint-Gobain Ireland.
- **Packaging, pulp & consumer goods** — SBTi net-zero value-chain pathways, recycled-content optimisation, multi-tier supplier geography. Example: Smurfit Westrock.
- **Energy, renewables & grid** — renewable-siting decisions, biomethane and green-hydrogen pathways, transitional portfolio planning. Examples: ESB, SSE Ireland, Bord na Móna, Gas Networks Ireland, EirGrid.

### How the partnership works under Sustain-FIT

Sustain-FIT is an Enterprise Ireland initiative co-funded by the EU Horizon Europe Marie Skłodowska-Curie Actions. Crucially, the enterprise partner **does not pay the Fellow’s salary** — salary, mobility and research costs are funded through the programme and administered by the host RPO (UCD). Intellectual property is managed under the Irish National IP Protocol 2019, with a written agreement between UCD and the company covering IP, confidentiality and secondment terms.

<ul style="list-style-type: none"> <li>• A real business challenge aligned with the EU Green Deal (e.g., Scope 3 hotspotting, CBAM readiness, product carbon footprint, supplierregion prioritisation).</li> <li>• A Secondment Mentor and a 6–12 month secondment placement during the 36-month fellowship.</li> <li>• Access to relevant operational, ERP, GIS or supply-chain data under NDA.</li> <li>• In-kind support (facilities, expertise, internal reviewers). No cash contribution required.</li> </ul>	<ul style="list-style-type: none"> <li>• Applied, postdoc-level research on the partner’s own operations — de-risked R&amp;D at zero salary cost.</li> <li>• Product- and plant-level carbon footprints, spatial hotspot maps, and ranked mitigation portfolios.</li> <li>• Audit-ready outputs supporting CSRD, CBAM, EU ETS, SBTi and EPD/ISO 14067 disclosures.</li> <li>• IP managed under the Irish National IP Protocol; rights to exploit results commercially per written agreement.</li> </ul>
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### Why UCD, Prof. Holden and this Fellow

Academic host: **University College Dublin**, one of Ireland’s leading research universities. Co-mentor **Prof. Nick Holden** (UCD School of Biosystems and Food Engineering) is an internationally recognised expert in life cycle assessment, systems analysis, and the sustainability of agri-food and bio-based systems, with a long track record of industry-linked research.

Applicant Fellow: **Dr. Guangcan Su**, postdoctoral researcher at Northwestern University, with a research programme combining agentic AI, GIS-LCA, and enterprise data integration. Recent work includes the development of evidence-tiered, ERP-grounded LCA workflows and the AI-LCA Score benchmark for agentic sustainability assessment.

### Timeline — Sustain-FIT Call 2

<b>Stage 1 — Project Formation</b>	2 March – 30 April 2026 (expressions of interest from partner companies needed now)
<b>Stage 2 — Application Submission</b>	1 – 29 May 2026 (submitted by the postdoc Fellow)

<b>What the enterprise partner provides</b>	<b>What the enterprise partner receives</b>
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<b>Stage 3 — Evaluation &amp; Interviews</b>	June – September 2026
<b>Funding decisions</b>	Q4 2026; fellowship begins early 2027 (36 months)

### Next step

A 30-minute exploratory call to scope a business challenge that fits your organisation. An expression of interest by **30 April 2026** is sufficient to join the application; full project co-design happens in May.

**Prof. Nick Holden**, UCD School of Biosystems and Food Engineering — [nicholas.holden@ucd.ie](mailto:nicholas.holden@ucd.ie)

**Dr. Guangcan Su**, Sustain-FIT Fellowship Applicant — [guangcansu@gmail.com](mailto:guangcansu@gmail.com)

# Curriculum vitae

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&

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## Guangcan Su, Ph.D.



Northwestern University, Evanston, IL 60208, United States

Researcher specialising in **life cycle** and **techno-economic assessment** of circular **bioeconomy systems**, with expertise in **agri-food side-stream valorisation**, biorefinery design, and data-driven sustainability modelling. Proven ability to integrate rigorous **process simulations** (Aspen Plus) with holistic environmental and economic impact assessments to evaluate the scale-up of emerging technologies. Record of 14 first-author or co-first-author publications in top-tier journals, including *Nature Synthesis*, *Energy & Environmental Science*, and *Renewable and Sustainable Energy Reviews*. Experienced in cross-sector industrial collaborations, leading systems analysis for decarbonisation, and assessing regional cascading biomass value chains.

## Education

### Universiti Malaya

### Kuala Lumpur, Malaysia

Ph.D. in Mechanical Engineering (Advisors: Hwai Chyuan Ong & N.W.M. Zulkifli) *Sep 2020-Mar 2024*

Dissertation: Comprehensive study on the pyrolysis of oil palm wastes for bioenergy production

Methodology: Conducted investigations integrating TEA and LCA to evaluate the carbon intensity, massenergy balances, and economic feasibility of biorefining and agro-waste valorization pathways.

### Jiangsu University

### Zhenjiang, China

M.S. in Mechanical Engineering (Advisor: Hanping Mao)

*Sep 2015-July 2018*

Dissertation: Research on wireless channel propagation characteristics and wireless sensor network control systems under greenhouse environment

### Nanjing Institute of Technology

### Nanjing, China

B.S. in Mechatronic Engineering

*Sep 2010-July 2014*

## Academic Experience

## Project Experience

### Northwestern University

Evanston, IL, USA

Postdoctoral Scholar (Advisors: **Edward H. Sargent & Jennifer B. Dunn**)

Mar 2024- Present

- **International Industry Collaboration (Denmark):** Partnered with Danish bio-innovation leaders (Copenhagen Process ApS and Novonesis A/S) to conduct systems analysis on upcycling organic waste and electricity for microbial proteins, informing industrial benchmarking against conventional proteins.
- **Evaluating Hybrid Abiotic-Biological Systems for CO<sub>2</sub>/CO Transformations (Gates Foundation):** Developed plant-scale TEA and LCA models for hybrid abiotic-biological systems, quantifying multiscenario land, water, and GHG trade-offs to outline strategies toward cost parity.
- **Agentic Spatio-Temporal LCA Framework for Decarbonization:** Engineered an Agentic SpatioTemporal LCA Framework utilizing Python and LLM APIs to parse unstructured procurement data, autonomously executing complete ISO 14044-compliant Scope 3 LCA workflows within 30 minutes per study (a ~1,000x speedup). Constrained predictive discrepancies to <15% (MAPE = 8.3%) against literature benchmarks while reducing per-study computational inference costs to under \$1.00, delivering robust data infrastructure for enterprise sustainability reporting.
- **Midwest Nuclear Direct Air Capture Hub (U.S. Department of Energy):** Led LCA/TEA modelling for large-scale carbon capture integration, producing visual analytics and reports that supported federal stakeholders in strategic siting and investment decisions.

### Universiti Malaya

Kuala Lumpur, Malaysia

Ph.D. (Advisors: Ong Hwai Chyuan, currently at Sunway Univ. & N.W.M. Zulkifli)

Sep 2020-Mar 2024

- **Bioenergy & Agro-Waste LCA (Malaysia SATU Joint Research Scheme):** Designed and evaluated carbon-negative co-production systems utilizing complex agri-food side-streams (e.g., animal manure, bagasse, oil palm) via thermochemical cascading processes. Conducted Hybrid LCA and state-level spatial-temporal distribution analysis to quantify regional global warming potential (GWP) reduction strategies for biomass value chains.
- **Data-Driven Process Optimization:** Leveraged Python/R machine learning algorithms to develop data-driven models predicting sustainability metrics and biochar properties from diverse lignocellulosic biomass characteristics.

## Skills and Techniques

- **LCA & Environmental Assessment:** GREET 2024, openLCA, Hybrid LCA, Spatio-Temporal GISLCA, GHG balance assessment, Land use & Water footprint
- **Circular Bioeconomy Systems, Biorefinery Design & Value-Chain Assessment:** Holistic sustainability assessment, mass-energy balances, system dynamics, and waste-to-products pathways
- **Scientific Programming & Data Science:** Python (Machine Learning/Data Analytics), R language, MATLAB, Microsoft Excel VBA, ArcGIS
- **Process Modelling & TEA:** Aspen Plus (deep expertise in thermochemical processes), rigorous Techno-Economic Analysis, multi-scenario sensitivity assessment

## Publications

- **Su, G.,** Mohd Zulkifli, N. W.\*, Ong, H. C., Ibrahim, S., Cheah, M. Y., Zhu, R., & Bu, Q. (2023). Copyrolysis of medical protective clothing and oil palm wastes for biofuel: Experimental, technoeconomic, and environmental analyses. *Energy*, 273, 127221. (Highlight: *Experimental characterization coupled with Aspen Plus modeling; comprehensive cradle-to-gate LCA and TEA of complex hybrid waste thermochemical conversion*)

- **Su, G.**, Jiang, P., Ong, H. C.\*, Zhu, J., Amin, N. A. S., Mohd Zulkifli, N. W., & Ibrahim, S. (2023). Coproduction of biochar and electricity from oil palm wastes for carbon dioxide mitigation in Malaysia. *Journal of Cleaner Production*, 423, 138749. (Highlight: spatial-temporal trajectory mapping, simulation, TEA & LCA; quantitative assessment of carbon farming and GHG abatement potential)
- **Su, G.**, Mohd Zulkifli, N. W.\*, Ong, H. C., Ibrahim, S., Bu, Q., & Zhu, R. (2022). Pyrolysis of oil palm wastes for bioenergy in Malaysia: A review. *Renewable and Sustainable Energy Reviews*, 164, 112554. (Highlight: Bibliometric network analysis, system-level review of regional agricultural bioeconomy, and evaluation of biochar for soil amendment and carbon sequestration)
- Chen, Y.†, Wang, P.†, Mao, Y.†, **Su, G.†** (Co-first author), Liu, H., Peng, B., Liu, Z., Ze, H., Wang, Y., Hu, X., Li, J., Fan, L., Alahmed, A., Jamal, A., Gereige, I., Lee, S., Dunn, J. B., Wang, Z.\*, Xie, K.\*, & Sargent, E. H.\* (2026). Dilute alloy electrocatalysts enable asymmetric C-C coupling for ethylene production from a CO<sub>2</sub> post-capture liquid. *Nature Synthesis*. (Highlight: Executed cradle-to-gate LCA & TEA for electrified ethylene production)
- Liu, H.†, Shin, H.†, Li, X.-Y.†, **Su, G.†** (Co-first author), Ou, P., Wang, Y., Chen, L., Yu, J., Chen, Y., Xia, R., Lee, G., Lee, K.-S., Yu, C., Wang, P., Choi, D., Zhou, D., Tian, C., Gereige, I., Alahmed, A., Jamal, A., Farha, O. K., Boettcher, S. W., Dunn, J. B., Xie, K.\*, & Sargent, E. H.\* (2025). Hierarchically porous carbon supports enable efficient syngas production in electrified reactive capture. *Energy & Environmental Science*, 18, 6628. (Highlight: Conducted comprehensive TEA & LCA for reactive carbon capture for syngas production)
- **Su, G.**, Jiang, P., Zhou, H., Mohd Zulkifli, N. W.\*, Ong, H. C., & Ibrahim, S. (2024). Integrated production of methanol and biochar from bagasse and plastic waste: A three-in-one solution for carbon sequestration, bioenergy production, and waste valorization. *Energy Conversion and Management*, 307, 118344. (Highlight: Aspen Plus modeling, Hybrid LCA, and state-level spatial-temporal analysis)
- **Su, G.**, Mohd Zulkifli, N. W.\*, Liu, L.\*, Ong, H. C., Ibrahim, S., Yu, K. L., Wei, Y., & Bin, F. (2023). Carbon-negative co-production of methanol and activated carbon from bagasse pyrolysis, physical activation, chemical looping, and methanol synthesis. *Energy Conversion and Management*, 293, 117481. (Highlight: TEA and LCA, simulation, carbon-negative system design for circular bioeconomy)
- **Su, G.**, Jiang, P. (2024). Machine learning models for predicting biochar properties from lignocellulosic biomass torrefaction. *Bioresource Technology*, 399, 130519. (Highlight: Python/R programming, ML algorithms, and SHAP feature importance analysis; data-driven prediction for biomass characteristics)
- Zhou, B.†, Liu, H.†, **Su, G.**, Shin, H., Li, X.-Y., Ze, H., Liang, Y., Peng, B., Ni, W., Chen, Y., Zhu, W., Yu, C., Chen, Y., Ou, P., Xie, K.\*, & Sargent, E. H.\* (2025). Electrosynthesis of CO from an electrically pH-shifted DAC post-capture liquid using a catalyst: support amide linkage. *Joule*, 9, 101883. (Highlight: Executed system-level LCA and TEA for an integrated DAC-to-CO electrosynthesis pathway, assessing its potential for scalable industrial decarbonization and clean power integration)

## Under Review

- **Su, G.†**, Xie, K.†\*, Lee, S. H., Stephanopoulos, G., Dunn, J. B.\*, & Sargent, E. H.\*. Carbon and energy to food without agriculture for climate-resilient food systems. *Nature*, (Under Review) (Highlight: Developed system-level LCA and TEA models for hybrid abiotic-biological food production; conducted dynamic time-series forecasting to demonstrate production cost and net-negative carbon emissions and 10–90x reductions in land and water footprints compared to conventional agriculture)
- Xu, X.†, Li, Y.†, **Su, G.†**, (Co-first author) Shin, H.†, Ze, H., Liang, Y., Huang, J., Liu, H., Musgrave, C.B.III, Li, P., Li, J., Menon, A., Kim, J., Xia, R., Zheng, D., Zhou, B., Dunn, J. B., Goddard, W. A. III\*, Xie, K.\*, & Sargent, E. H.\*. Cascade-terminating catalysts enable efficient electroproduction of concentrated H<sub>2</sub>O<sub>2</sub>.

*Nature Catalysis*, (Under Review) (Highlight: distillate cyclohexanone oxime via Aspen plus; conducted LCA & TEA calculations and systematically comparing the proposed system with multiple conventional production pathway)

- Liu, H.†, Shin, H.†, Li, Y.†, **Su, G.†**, (Co-first author) Peng, B., Wang, Y., Huang, J. E., Song, J.-Y., Zhou, B., Chen, Y., An, H., Ze, H., Musgrave, C. B. III, Dunn, J. B., Goddard, W. A. III\*, Xie, K.\*, & Sargent, E. H.\*. Proton source selection enables stable reactive capture for fuels from air. *Nature Catalysis*. (Under Review) (Highlight: Conducted LCA & TEA to evaluate a closed-loop DAC-to-CO system)

## Teaching and Supervision Experience

- Master Student Supervision (Universiti Malaya): Ahmed Faizal Bin Ayub Khan, Thesis title: *Catalytic co-pyrolysis of medical waste and coconut shell to produce high-quality biofuel*.
- Undergraduate Supervision (Universiti Malaya): Ashwin Kumar, Thesis title: *Effects of pyrolysis conditions on durian shell: pyrolysis characteristics and biochar properties*.
- Academic Mentoring & Teaching Support (Nanjing Institute of Technology): Served as a Student Counselor Assistant, providing academic advising, facilitating group discussions, and managing pastoral care for a cohort of over 40 undergraduate students.

## Funded Research Projects and Grants

- Evaluating Hybrid Abiotic-Biological Systems for CO<sub>2</sub>/CO Transformations (Gates Foundation) | Lead Modeler & **Contributor to Successful Grant Renewal Proposal**
- Midwest Nuclear Direct Air Capture Hub (U.S. Department of Energy) | Lead LCA/TEA Analyst
- Development of Sustainable Bio-jet Fuel from Oil Palm Waste Feedstocks (UM International Grant (2022-2024)) | Core Investigator

## References

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