

CONFIDENTIAL

RESEARCH AGREEMENT

BETWEEN

Shell India Markets Private Ltd

AND

Indraprastha Institute of Information Technology Delhi

FOR

Carbon footprint optimizer for data and computational science workflow

Agreement No. CW764055

THIS AGREEMENT IS MADE as of the June 30, 2023 by:

SHELL INDIA MARKETS PRIVATE LTD, a company incorporated under the Companies Act, 1956 of India and having its registered office at 2nd Floor, Campus 4A, RMZ Millenia Business Park, 143 Dr MG Road, Perungudi, Chennai 600096, Inida, hereinafter called “**Shell**”

and

Indraprastha Institute of Information Technology, Delhi (hereinafter "IIIT-Delhi") is a State University created by an act of Delhi State Government (**The IIIT Delhi Act, 2007**) empowering it to grant degrees in engineering domain with specific focus in the area of Information Technology. IIIT-Delhi was officially established on 10th June, 2008 as per the notification in the Delhi Gazette. IIIT-Delhi having its campus at Okhla Phase 3, New Delhi 110020, India, hereinafter called “**Research Partner**”.

WHEREAS:

- A. Shell wishes to engage the Research Partner for the provision of certain research services in the area of **Carbon footprint optimizer for data and computational science workflow**; and
- B. The Research Partner is willing to arrange for such a study to be carried out.

NOW THEREFORE IT IS AGREED AS FOLLOWS:

1. DEFINITIONS AND INTERPRETATION

The following expressions shall have the meanings specified:

“Affiliate” with respect to Shell means (a) Shell plc and any entity other than Shell which is at the time in question directly or indirectly controlled by Shell plc.; (b) any entity which is managed or operated by Shell or any entity as defined in (a) above; (c) any entity which has a service agreement with Shell or any entity as defined in (a) or (b) above pursuant to which it pays or recovers on a cost-sharing basis a proportion of certain of the costs of Shell or such entity pursuant to a cost allocation key; and/or (d) any entity that has a production sharing arrangement with Shell or an entity as defined in (a) or (b) above solely for purposes of that production sharing arrangement. For the purpose of this definition, a particular entity is (i) directly controlled by another entity or entities if that latter entity owns or those latter entities together own fifty percent (50%) or more of the ownership interest of, or of the voting or contractual rights in, the particular entity; and (ii) is indirectly controlled by an entity or entities if a series of entities can be specified, beginning with that latter entity or entities and ending with the first mentioned entity, so related that each entity of the series (except the latter entity or entities) is directly controlled by one or more of the entities earlier in the series. Affiliate” with respect to Research Partner means any company which is directly or indirectly wholly owned by Research Partner;

“Agreement” means this agreement including the appendices to this Agreement, as amended, varied or supplemented from time to time pursuant to Clause 23 hereof;

“Anti-Corruption Laws” means the United States Foreign Corrupt Practices Act of 1977, the United Kingdom Bribery Act 2010 (as amended from time to time), and all other Laws that prohibit tax evasion, money laundering or otherwise dealing with the proceeds of crime, or the bribery of, or

the providing of unlawful gratuities, facilitation payments or other benefits to, any Government Official or any other person;

“Books and Records” means books, accounts, contracts, records, and documentation, in electronic format, or otherwise, in respect of the Agreement and performance of the Study.

“Force Majeure Event” means the events qualifying as a Force Majeure Event as expressly set out in the Agreement;

“Government Official” means: (a) any official or employee of any government, or any agency, ministry, or department of a government (at any level); (b) anyone acting in an official capacity for a government regardless of rank or position; (c) any official or employee of a company wholly or partially controlled by a government (e.g. a state-owned oil company), political party, or any official of a political party; (d) any candidate for political office, or any officer or employee of a public international organisation (e.g. the United Nations or the World Bank); and (e) any immediate family member (meaning a spouse, dependent child, or household member) of any of the foregoing;

“Intellectual Property Rights” means patents, copyrights (including rights in computer software), database rights, design rights and rights in proprietary technical information and know-how, trade secrets and inventions, trademarks, service marks and design marks, all whether registered or not and including all applications for any of them and all equivalent rights in all parts of the world, whenever and however arising for their full term, and including any divisions, re-issues, re-examinations, continuations, continuations-in-part, and renewals;

“Indemnify” means release, save, indemnify, defend, and hold harmless;

“Laws” means all applicable national, regional, provincial, state, municipal or local statutes, ordinances or other laws (including but not limited to Anti-Corruption Laws); rules, regulations and orders issued by authorities; judgments and orders of courts of competent jurisdiction; by-laws or any rules, codes or directions or any licence, consent, permit, authorisation or other approval required by any public body or authority, local or national agency, department, inspector, ministry, official or public or statutory person (whether autonomous or not);

“Liabilities” means liabilities for all claims, losses, damages, costs (including legal fees), and expenses;

“Notice” means a notice, subpoena, order or other legal process, including any request for disclosure of information pursuant to any applicable Freedom of Information legislation;

“Paper” means a paper as described in Clause 9.1;

“Party” means either Shell or the Research Partner as the context requires and “Parties” shall mean Shell and the Research Partner collectively;

“Purchase Order” means any order issued by Shell to the Research Partner with respect to a purchase for the purpose of the Study;

“Related Party” means in relation to a Party or any of its Affiliates:

- (a) any person employed by that Party or any of its Affiliates or any Subcontractor acting on behalf of that Party or any of its Affiliates;
- (b) any director or other officer of that Party or any of its Affiliates;
- (c) any Subcontractor acting for or on behalf of that Party or any of its Affiliates; and
- (d) any person acting for or on behalf of that Party or any of its Affiliates;

and “Related Parties” shall mean the plural;

“Research Associate” means the person(s) nominated by the Research Partner in accordance with Clause 3.2;

“Research Partner Personnel” means any individual employed or supplied by Research Partner whether directly or indirectly and assigned to work in connection with the performance of this

Agreement whether or not an employee of Research Partner, and includes students, Research Associates, Supervisors, as well as Subcontractors of Research Partners and their personnel;

“Restricted Jurisdiction” means a country, state, territory or region which is subject to comprehensive economic or trade restrictions under Trade Control Laws. As of the date of this Agreement, Restricted Jurisdictions include Cuba, Crimea and Sevastopol, Iran, North Korea, Sudan and Syria;

“Restricted Party” means any individual, legal person, entity or organisation that is: (i) resident, established or registered in a Restricted Jurisdiction; (ii) classified as a US Specially Designated National or otherwise subject to blocking sanctions under Trade Control Laws; (iii) directly or indirectly owned or controlled (as these terms are interpreted under the relevant Trade Control Laws), or acting on behalf of, persons, entities or organisations described in (i) or (ii); or (iv) a director, officer or employee of a legal person, entity or organisation described in (i) to (iii).

“Results” means any and all information, reports, data, databases, drawings, computer programs (including source code, object code and documentation), semi-conductor topography, mask work, spread sheets, presentations, analyses, results, conclusions, findings, solutions, calculations, studies, concepts, codes, manuals, inventions, models, designs, prototypes, magnetic data, flow charts, recommendations, working notes, specifications or other information, documents, materials, or goods which arises or is made, created, generated or discovered under the Agreement in connection with Study;

“Shell Monitor” means the person(s) nominated by Shell in accordance with Clause 3.4;

“Shell Information” means data, software and all technical, commercial, financial, legal or other information, and items that record such data, software or information disclosed by or on behalf of Shell and/or an Affiliate of Shell in connection with the Study or under this Agreement;

“Study” means all activities and obligations to be performed by or on behalf of Research Partner under this Agreement, including the study having the scope described in APPENDIX I;

“Subcontractor” means any party to a subcontract with a Party or an Affiliate thereof other than Shell and Research Partner;

“Supervisor” means the person(s) nominated by the Research Partner in accordance with Clause 3.3;

“Thesis” means a thesis written by a Research Associate as described in Clause 9.1;

“Trade Control Laws” means any laws concerning trade or economic sanctions or embargoes, Restricted Party lists, trade controls on the imports, export, re-export, transfer or otherwise trade of goods, services or technology, and any other similar regulations, rules, restrictions, orders or requirements having the force of law in relation to the above matters and in force from time to time, including those of the European Union, the United Kingdom, the United States of America or any government laws in relation to the above matters applicable to a party to the Agreement.

“Worksite” means all the lands, waters, facilities, properties and any other places including, but not limited to, storage facilities, offshore installations, floating construction equipment, vessels (including the area approved by anchor patterns), offices, workshops, and messing facilities, on, under, in or through which work in connection with the Agreement will be performed by Research Partner and Research Partner Personnel, which are owned and/or operated by Shell and/or Affiliates of Shell.

2. COMMENCEMENT AND DURATION

This Agreement shall come into effect on **June 30, 2023**, and unless terminated earlier in accordance with Clause 13, shall continue in force until **June 29, 2025**.

3. PERSONNEL AND LOCATION

- 3.1 The Research Partner undertakes to carry out the Study with all professional skill, care and diligence.
- 3.2 The Research Partner shall assign Research Associate to work on the Study for the duration of the Study. The Research Associate's contact details, including name, address, phone and email, will be confirmed in writing to Shell Monitor when onboarded and available.
- 3.3 The Research Partner shall arrange for the work of the Research Associate on the Study to be supervised by Dr. Vivek Kumar. The Supervisor's contact details are as follows:
- Dr. Vivek Kumar
B-506, R&D Block, IIIT-Delhi, Okhla Phase 3, New Delhi 110020, India
Tel: +91-11-26907441
Email: vivekk@iiitd.ac.in
- 3.4 Shell shall nominate one of its employees to monitor the progress of the Study and to act as contact point with the Research Partner. The initial Shell Monitor shall be Dr. Chiranjib Sur. The initial Shell Monitor's contact details are as follows:
- Dr. Chiranjib Sur
Head of Engineering, Scientific Software
Information and Digital Engineering
Projects and Technology
- Shell India Markets Private Limited
SBO office, Bagmane Solarium City, Xenon North
Brookefield, Bengaluru, India 560037
Email: Chiranjib.Sur@shell.com
Phone: +91 72590 07247
- 3.5 The Study shall be carried out at designated premises of Research Partner in the **India** unless otherwise agreed between Shell and the Research Partner.

4. DELIVERABLES

- 4.1 The Research Partner undertakes to arrange for the Supervisor to:
- (a) keep the Shell Monitor fully informed of the progress on the Study by providing written reports at regular intervals to be agreed; and
 - (b) provide the Shell Monitor with the Results, if any, in the form of written reports at regular intervals to be agreed.
- 4.2 The Research Partner shall ensure that the Shell Monitor receives a copy of the final report of the Study promptly after completion of the Study. Such report shall set out all Results of the Study.
- 4.3 The Research Partner shall supply to the Shell Monitor:
- (a) copies of the object and source code and documentation of any software comprised in the Results; and
 - (b) all samples and other materials (other than draft reports) containing Results.

5. PAYMENT

- 5.1 In consideration of the carrying out of the Study, the supply of the Results and the grant of rights to Shell as specified in Clause 8 Shell shall make the of payment of USD 52800 as unrestricted grant in several instalments in accordance with APPENDIX II.
- 5.2 Shell shall pay the Research Partner within sixty (60) days (unless otherwise stated by Shell) of receipt by Shell of a correctly prepared and properly supported invoice. Shell reserves the right to pay only the undisputed portion of any disputed invoice. The parties shall endeavour to settle at

the earliest possible date any invoicing matters in dispute. An invoice is considered complete when Shell is able to verify the legitimacy or accuracy of the invoice using the information provided by the Research Partner and all supporting documentation.

- 5.3 The Research Partner shall state the Agreement number and the Purchase Order number on the invoice and send its invoices to the address specified in the Purchase Order.

6. SUPPLY OF INFORMATION

- 6.1 Shell shall arrange for the disclosure to the Research Partner of such Shell Information as Shell deems necessary to ensure satisfactory progress is made in the Study.

7. CONFIDENTIALITY OBLIGATIONS

- 7.1 The Research Partner undertakes that it shall not, and warrants that the Supervisor and the Research Associate shall not, without the prior written consent of Shell:

- (a) disclose to any third party any Shell Information or the Results however Research Partner may disclose Shell Information or the Results to students (i) agreed by Shell in writing in advance to perform work in the Study and (ii) who have signed a confidentiality and restricted use agreement of at least as stringent obligations of confidentiality and restricted use as stated in this Clause 7 without further right to disclose the Shell Information or Results; or

- (b) use any Shell Information or the Results for any purpose other than the Study.

- 7.2 The Research Partner may disclose Shell Information or the Results only to those Research Partner Personnel who:

- (a) have a reasonable need to know and use such information in furtherance of completing the Study;
- (b) have been informed of the confidential nature of the Shell Information and the Results in question; and
- (c) are bound by obligations no less stringent than those assumed by the Research Partner hereunder without a right to further disclose;

provided the Research Partner shall remain fully liable towards Shell for any Research Partner Personnel disclosure of Shell Information or Results or use of Shell Information or Results for any purpose other than the Study that, if committed by the Research Partner, would be a breach of the Research Partner's confidentiality and restricted use obligations hereunder.

- 7.3 The obligations in Clauses 7.1 and 7.2 shall:

- (a) not apply to any Shell Information that, at the time it is received or obtained by the Research Partner, is lawfully known by the Research Partner without binder of secrecy or is publicly available; and
- (b) cease to apply to any Shell Information or Results which, after it is received or obtained by the Research Partner:
 - (i) is received by the Research Partner without binder of secrecy from a source free to disclose it other than Shell and/or any Affiliate of Shell;
 - (ii) becomes publicly available other than as the result of a breach of this Agreement;
 - (iii) is approved for release in advance and in writing by an authorised representative of Shell and is released in accordance with the Shell approval; or
 - (iv) has been approved for publication in accordance with Clause 9 and is published in accordance with the approval.

- 7.4 If the Research Partner receives a Notice seeking disclosure of Shell Information or Results, the Research Partner shall immediately notify Shell and the Shell Monitor in order to allow Shell the opportunity to oppose the Notice or to seek a protective order. If requested by Shell, the Research Partner shall co-operate fully with Shell in contesting such disclosure. Except as such demand shall have been limited, quashed or extended, the Research Partner may thereafter comply with such demand, but only to the extent required by law. Where Shell has obtained a protective order, nothing in this Agreement shall be construed as authorising the Research Partner to use in any manner or disclose Shell Information or Results to parties other than such governmental or judicial agency or body beyond the scope of the protective order.
- 7.5 Information shall only be within the exceptions in Clause 7.3 to the extent that the Research Partner can establish the facts with adequate proof.
- 7.6 Specific disclosures made hereunder shall not be deemed to be subject to any of the exceptions in Clause 7.3 merely because they are embraced by general disclosures in the public knowledge or literature or in the possession of the Research Partner, the Supervisor and/or the Research Associate.
- 7.7 Any combination of features disclosed hereunder shall not be deemed subject to the exceptions in Clause 7.3 merely because individual features are in the public knowledge or literature or in the possession of the Research Partner, the Supervisor and/or the Research Associate.
- 7.8 In the event this Agreement is terminated pursuant to Clause 13.2, Research Partner will promptly return or destroy any Shell Information and Results, delete it from electronic storage, and delete or destroy all extracts or analyses that reflect any Shell Information or Results.
- 7.9 Research Partner will not broadcast or publish any external communications related to this relationship or agreement.

8. RIGHTS IN RESULTS

- 8.1 (a) Subject to Clauses 7, 8.1 (b) and 9, all right, title and interest in and to the Results solely created, generated, or discovered by the Research Partner or any Research Partner Personnel, and all Intellectual Property Rights therein other than trademarks, services marks, designs and design marks, vest in the Research Partner upon creation, generation, or discovery thereof. The Research Partner shall have the exclusive right to file patent applications in respect of inventions embodied in such Results in its own name and at its own expense in such countries as it deems appropriate.
- (b) All Intellectual Property Rights generated, created or discovered hereunder that use or are an improvement to Shell's or Shell Affiliates' Intellectual Property Rights, or are generated, created or discovered using, or are an improvement to, Shell Information, hereby vest in Shell or its designee upon the generation, creation and/or discovery thereof. Research Partner will execute, and will cause Research Partner Personnel to execute documents, and take all other steps as may reasonably be necessary to document the ownership of Shell or its designee in such Intellectual Property Rights. Research Partner irrevocably waives, and will cause Research Partner Personnel to irrevocably waive, any moral or similar, non-transferable rights that Research Partner or Research Partner Personnel may have in such Intellectual Property Rights vesting in Shell or its designee under this Clause 8.1 (b).
- 8.2 The Research Partner hereby grants to Shell and to Shell Affiliates from the date any such Results are created a perpetual, irrevocable, worldwide, non-exclusive, royalty-free license to use, have used, make, have made, operate, have operated, import, have imported, export, have exported, copy, have copied, adapt, have adapted, translate, have translated, reproduce, have reproduced, disclose, have disclosed, distribute, have distributed, modify, have modified, improve, have improved, create derivative works of, have derivative works created of, repair, have repaired, and otherwise exploit and have exploited the Results.

8.3 The Research Partner, warranting that it is free to do so, grants Shell and Shell Affiliates a perpetual, irrevocable, non-exclusive, royalty-free, worldwide licence, with a right to grant sublicenses, under:

- (a) any Intellectual Property Rights of the Research Partner; and
- (b) any Intellectual Property Rights of third parties licensed to the Research Partner with the right to grant sub-licences to third parties,

to use, have used, make, have made, operate, have operated, import, have imported, export, have exported, copy, have copied, adapt, have adapted, translate, have translated, reproduce, have reproduced, disclose, have disclosed, distribute, have distributed, modify, have modified, improve, have improved, create derivative works of, have derivative works created of, repair, and have repaired the Results for any purpose solely to the extent necessary to use or exploit the Results as licensed. The Research Partner agrees that it shall not use the Intellectual Property Rights of third parties to carry out the Study where it is not free to provide a sub-licence to Shell as set out in this Clause 8.3.

8.4 The Research Partner shall be solely liable for employee compensation or remuneration due to inventors, other than employees of Shell and Affiliates of Shell, under any intellectual property legislation.

8.5 At the request of Shell, such request to be made before expiry of four (4) years from the date of completion or termination of the Study, the Research Partner will offer Shell the right and licence referred to in Clause 8.2 on an exclusive basis on reasonable terms and conditions to be agreed separately between Shell and the Research Partner.

9. PUBLICATIONS BY THE RESEARCH PARTNER

9.1 Without prejudice to Clauses 7 and 8, Shell recognises that a Research Associate and/or the Supervisor may wish to publish some or all of the Results together with any relevant Shell Information as a paper within the Research Partner or in the open literature (“**Paper**”) and/or that the Research Associate may wish to submit a thesis containing the Results together with any relevant Shell Information for a higher degree from the Research Partner (“**Thesis**”).

9.2 Before publication of any Paper and prior to any submission of any Thesis, the Research Partner shall arrange for the Paper and/or Thesis to be given to Shell. Shell may examine and change the Paper and/or Thesis to enable Shell to protect the Results and to protect Shell Information and Intellectual Property Rights comprised in the Shell Information, including taking steps to file an application for patent.

9.3 At any time Shell may withhold its consent to the publication of any Shell Information or any portion of the Results in any Paper and/or Thesis.

9.4 Shell does not grant the Research Partner any rights or licenses in any of Shell’s or Shell Affiliates’ trademarks, service marks, trade or business names, or domain names.

10. WARRANTIES

10.1 Shell and/or its Affiliates make no representation and give no warranty as to the accuracy of Shell Information and/or as to its satisfactory quality, fitness or suitability for Research Partner's purpose. The Research Partner will receive and use Shell Information at its own risk.

10.2 The Research Partner warrants that the Results are the sole and original work of Research Partner Personnel involved in the Study.

11. FORCE MAJEURE

11.1 Shell and Research Partner are each excused from performance of the affected part of an obligation of the Agreement while performance is prevented by a Force Majeure Event unless

the event: (i) was contributed to by the fault of the party or was due to circumstances that could have been avoided or mitigated by the exercise of reasonable diligence by (A) any member of Research Partner Personnel or its Related Parties where Research Partner claims force majeure or (B) any Affiliate of Shell where Shell claims force majeure; or (ii) relates to an inability to make payments of money or secure funds.

- 11.2 Only the following are Force Majeure Events: (i) riots, wars, blockades, or threats or acts of sabotage or terrorism; (ii) earthquakes, floods, fires, named hurricanes or cyclones, tidal waves, tornadoes, or other natural physical disasters; (iii) radioactive contamination, epidemics, maritime or aviation disasters; (iv) strikes or labour disputes at a national or regional level or involving labour not forming part of Research Partner and its Related Parties or Shell, which materially impair the ability of the party claiming force majeure to perform the Agreement; (v) government sanctions, embargoes, mandates, or laws that prevent performance; (vi) inability of a party to timely obtain licences, permits, or governmental consents required for performance; or (vii) non-performance of a party's Subcontractor where the Subcontractor has been or is affected by one of the above Force Majeure Events. However, performance will only be excused under this sub-article if Parties agree that substitute performance by another Subcontractor is impracticable under the circumstances.
- 11.3 A party whose performance is delayed or prevented will: (i) notify the other party without delay; (ii) use all reasonable endeavours (including acceleration of schedules on resumption of performance) to mitigate the effects; and (iii) provide on a continuing basis plans for resumed performance and revised schedules.
- 11.4 Shell may terminate the Agreement if any Force Majeure Event results in a delay that exceeds ninety (90) consecutive or one hundred and eighty (180) cumulative days.

12. RESEARCH PARTNER PERSONNEL AND SUBCONTRACTING

- 12.1 Research Partner is responsible for any Study performed by and all activities, omissions, and defaults of Research Partner Personnel as if they were the activities, omissions, or defaults of Research Partner.
- 12.2 Research Partner may not subcontract any part of its obligations under the Agreement except as agreed in writing by Shell. Research Partner will ensure that subcontracts are in all material respects consistent with the terms and conditions of the Agreement, including the terms and conditions of Clauses 7 and 8, in particular by extending the obligations under Clause 8.2 and 8.5 to include those Results obtained by Subcontractor and under Clause 8.3 to include Subcontractor's Intellectual Property Rights.
- 12.3 Research Partner agrees to indemnify Shell and its Affiliates for liabilities arising from Research Partner's use of Subcontractors in the performance of the Agreement.

13. TERMINATION

- 13.1 If a Party breaches any of its obligations under this Agreement and has not remedied and/or indemnified the other Party for such breach within sixty (60) days after breaching Party has received notice from the non-breaching Party requiring the breaching Party to remedy and/or indemnify the other Party for such breach, then unless the breaching Party refers the matter to arbitration under Clause 24 before the end of the sixty (60) days, the non-breaching Party may terminate this Agreement by giving thirty (30) days written notice to the breaching Party.
- 13.2 Shell may terminate the Study with immediate effect by written notice in the event that:
- (a) the Supervisor and/or Research Associate cease to be involved in the Study and the Research Partner is unable to find an alternative person(s) acceptable to Shell to supervise and/or carry out the Study, as the case may be;
 - (b) following consultation with the Research Partner Shell is of the opinion, that insufficient progress has been made towards the aims of the Study;

- (c) the direction of the Study has changed significantly from that originally contemplated by Shell such that Shell is no longer interested in funding the Study; or
- (d) in the reasonable opinion of Shell, the Research Partner or Research Partner Personnel, when performing work in connection with this Agreement:
 - (A) commits any or causes Shell or any of its Related Parties to be in breach of applicable Anti-Corruption Laws;
 - (B) breaches Clause 14.6 of this Agreement;
 - (C) commits any or causes Shell or any of its Related Parties to be in breach of applicable competition laws; or
 - (D) commits a material breach of the Laws not mentioned in paragraphs (A) and (C) of this Clause; or
 - (E) any conflict of interest arises between the Research Partner or any of its Related Parties and Shell or any of its Related Parties, unless accepted in writing by Shell.

13.3 Shell may terminate the Agreement or reduce Study for convenience at its own discretion with thirty (30) days prior written notice.

13.4 Provided that Shell satisfies its obligations under Clause 5 that are outstanding at the date of termination, Shell shall have no further obligations toward the Research Partner with respect to the Study after such termination.

14. COMPLIANCE WITH ANTI-CORRUPTION LAWS

14.1 The Research Partner represents that, in connection with this Agreement and related matters:

- (a) it is knowledgeable about Anti-Corruption Laws and will comply with those laws;
- (b) neither it nor a Related Party have made, offered, authorised or accepted or will make, offer, authorise, or accept, any payment, gift, promise, or other advantage, whether directly or through any other person or entity, to or for the use or benefit of any Government Official or any other person where that payment, gift, promise or other advantage would: (i) comprise a facilitation payment; or (ii) violate the relevant Anti-Corruption Laws;

14.2 The Research Partner will immediately notify Shell if the Research Partner receives or becomes aware of any matter that is prohibited by Clause 14.1.

14.3 Shell's appointment of the Research Partner is expressly made on the basis that Anti-Corruption Laws and the Business Principles would not be violated. The Research Partner acknowledges that the contents of this Agreement may be disclosed by Shell to third parties for the purposes of demonstrating compliance with this Clause.

14.4 The Research Partner will maintain adequate internal controls and procedures to ensure compliance with Anti-Corruption Laws, including the ability to demonstrate compliance through adequate and accurate recording of transactions in its Books and Records.

14.5 The Research Partner affirms that neither it nor any of its Related Parties is a Government Official or other person who could assert illegal influence on behalf of Shell or its Affiliates. If any of the foregoing becomes a Government Official, the Research Partner will promptly notify Shell and remove that individual from performance in connection with the Study at Shell's request.

14.6 Shell will have the right to confirm compliance with Anti-Corruption Laws and record keeping by audit. The Research Partner will keep Books and Records available for audit while the Agreement is in effect and thereafter for ten years following termination of the Agreement.

14.7 The Research Partner will Indemnify Shell and its Related Parties for any Liabilities arising out of the Research Partner's breach of Anti-Corruption Laws or any related undertakings under this Clause 14.

15. LIABILITIES AND INDEMNITIES

- 15.1 Liability for loss of and damage to property and for personal injury, death, or disease to any person, arising in connection with the Agreement, will be determined in accordance with applicable Laws.
- 15.2 Neither party will be liable to the other for that other party's own consequential loss, or any punitive or exemplary damages that might be awarded in that party's favour, regardless of negligence or other fault.
- 15.3 Neither party excludes or limits its liabilities to the extent they may not be excluded under applicable Laws.

16. INSURANCE

- 16.1 Prior to commencement of performance, Research Partner will arrange any insurance required by applicable Laws and maintain that insurance in effect throughout the duration of the Agreement.
- 16.2 All insurance will be arranged with substantial insurers.
- 16.3 Satisfaction of the obligation to procure insurance and perform other actions in connection with this Clause 16 will not relieve Research Partner of any other obligations or Liabilities.
- 16.4 Shell may require Research Partner to provide certificates of insurance, evidence of policy exclusions and endorsements acceptable to Shell, or other proof of insurance. Shell reviewing or accepting any certificate, insurer, or terms or limits of insurance proposed by Research Partner, will not relieve Research Partner of any obligations or Liabilities.

17. HSSE & BUSINESS PRINCIPLES/CODE OF CONDUCT

17.1 The Research Partner acknowledges that it has actual knowledge of:

- (a) the Shell General Business Principles ("Business Principles") available at www.shell.com/sgbp, and the Shell Supplier Principles, available at www.shell.com/suppliers;
- (b) the Shell Code of Conduct, available at http://www.shell.com/home/content/aboutshell/who_we_are/our_values/code_of_conduct/; and
- (c) the Shell Global Helpline, available at http://www.shell.com/home/content/aboutshell/who_we_are/our_values/compliance_helpline/.

17.2 The Research Partner agrees that it and its Related Parties will adhere to and notify of violations of the principles contained in the Shell General Business Principles and Shell Supplier Principles (or where The Research Partner has adopted equivalent principles, to those equivalent principles) in all its dealings with or on behalf of Shell in connection with this Agreement and related matters. In the event that the Research Partner or any of its Related Parties supply staff that work on behalf of Shell or represent Shell, the Research Partner commits that such staff will behave in a manner that is consistent with the Shell Code of Conduct. The Research Partner shall notify Shell immediately if it becomes aware of any behaviour by Shell staff, the Research Partner or its Related Parties which is, or may be, inconsistent with the Shell General Business Principles, the Shell Code of Conduct or, where the Research Partner has adopted equivalent principles, their equivalent.

17.3 At Shell's request, the Research Partner will provide information to Shell as required to complete and fully respond to Shell's usual supplier questionnaires and due diligence to confirm compliance by Research Partner with Business Principles. As part of Shell's due

diligence, Research Partner will grant Shell or its representatives reasonable access to the Research Partner's facilities and sites.

17.4 In performing all work in connection with the Agreement, Research Partner shall ensure that all Research Partner Personnel will strictly comply with all applicable Laws. Whenever Research Partner Personnel are on a Worksite they shall behave in a manner which is consistent with Shell's requirements for the management of health, safety, security, and environmental protection, as well as any rules, procedures or codes of practice in force at the relevant Worksite. Research Partner shall at all times be aware of the Goal Zero principle and IOGP 459 Life Saving Rules. Research Partner confirms having received a copy of IOGP 459 Life Saving Rules (or alternatively, has taken notice of the Life Saving Rules at <https://www.iogp.org/life-savingrules/>).

18 FINANCIAL AND PERFORMANCE AUDIT

- 18.1 Shell will have the right to audit: (i) invoiced charges and proper invoicing; (ii) other Books and Records; and (iii) the performance of any other of Research Partners' obligations under the Agreement, including compliance with Anti-Corruption Laws, where capable of being verified by audit.
- 18.2 Based on the findings of the audit, the parties will settle any amounts charged incorrectly within forty five (45) days of any audit finding; and Research Partner will provide any Study, or refund, repair, replace, or re-perform any Study where the requirement to do so is identified by any audit within forty five (45) days of any audit finding.
- 18.3 Research Partner will keep Books and Records available for audit for the longer of the following periods: (i) five (5) years following termination of the Agreement or any longer period as required by applicable laws; or (ii) two (2) years after the period expires on any obligation of Research Partner to refund, repair, replace, or re-perform any Study (including correction of defects).
- 18.4 If a longer period is specified in the Agreement for retention of relevant records for compliance with Anti-Corruption Laws, Research Partner will comply with that requirement.

19 TRADE CONTROL

- 19.1 Research Partner warrants that it is knowledgeable about Trade Control Laws applicable to the performance of the Agreement including the lists of Restricted Parties. Research Partner shall comply with all applicable Trade Control Laws in the performance of this Agreement and in particular Research Partner undertakes that it shall not, and shall procure that its Related Parties shall not, do anything in connection with the performance of this Agreement which causes Shell to (a) be exposed to a risk of being added to any Restricted Party list or otherwise becoming the target of any national, regional or multilateral trade or economic sanctions under Trade Control Laws; or (b) be in breach of any Trade Control Laws.
- 19.2 Research Partner shall not source, purchase or procure any of the goods, products, software, information/technology or services to be delivered or provided to Shell under this Agreement, directly or indirectly from a Restricted Party or from a Restricted Jurisdiction unless specifically authorized to do so in writing by Shell.
- 19.3 Unless otherwise agreed by the Parties in writing, Research Partner will be responsible for obtaining any required authorisation, import, export or transfer licenses or any customs licenses which may be required pursuant to applicable Trade Control Laws for the Results. Where necessary, Research Partner shall provide Shell with applicable export classifications for the products supplied by Research Partner to Shell under this Agreement.
- 19.4 Notwithstanding anything to the contrary herein, nothing in the Agreement is intended, and nothing herein should be interpreted or construed, to induce or require Shell to act or refrain from acting (or agreeing to act or refrain from acting) in any manner which is inconsistent with, penalised or prohibited under Trade Control Laws or would otherwise expose Shell to a risk of being added to any Restricted Party list or otherwise becoming the target of any national, regional or multilateral trade or economic sanctions under Trade Control Laws. This Clause shall

- survive expiration or termination of this Agreement.
- 19.5 Shell shall not be obliged to perform any obligation under this Agreement, shall not be liable for damages or costs of any kind (including but not limited to penalties) for any delay or non-performance, and shall be entitled to suspend or terminate this Agreement with immediate effect, if Shell determines that: (a) such performance would expose Shell to a risk of being added to any Restricted Party list or otherwise becoming the target of any national, regional or multilateral trade or economic sanctions under Trade Control Laws and/or; or be in breach of any Trade Control Laws; (b) Research Partner has failed to comply with the requirements of this clause; or (c) Research Partner becomes a Restricted Party. In the event Shell suspends deliveries/supplies or terminates the Agreement pursuant to this clause, Shell shall not be liable to the other Party for any of the other Party's damages or losses for any delay or non-performance, except to refund any money paid by the other Party for the products/goods or services that were not delivered to the extent such refund is not inconsistent with Trade Control Laws.
- 19.6 Where requested to do so by Shell, Research Partner will supply Shell with such evidence as Shell may reasonably request to demonstrate Research Partner's compliance with this clause and to demonstrate that controls are in place which actively support such compliance.
- 19.7 Research Partner confirms that it has imposed or required the imposition of the conditions set out in this clause (or equivalent) on any direct or indirect supplier, or provider of the products, goods, services, software technology to be provided by the Research Partner to Shell under this Agreement.
- 19.8 Research Partner will ensure that (i) except with the prior written consent of Shell, Shell Information is not exported, provided or made available to any Restricted Jurisdiction or Restricted Parties (ii) subcontractors are not Restricted Parties and (iii) except with the prior written consent of Shell, Research Partner Personnel engaged in the Study are not Restricted Parties or nationals of a Restricted Jurisdiction. Without limiting the foregoing, Research Partner will at relevant times screen subcontractors and Research Partner Personnel against governmental lists to ensure none are a Restricted Party.
- 19.9 Research Partner shall indemnify Shell for any losses, liabilities (including but not limited to fines and penalties), damages, costs incurred by or claims or proceedings instituted against Shell arising from or in connection with Research Partner or its Related Parties failure to comply with this clause.

20. DATA PRIVACY

- 20.1 In the course of the performance of this Agreement, the parties may provide each other with information related to an identified or directly or indirectly identifiable individual ("Personal Data"), the processing and transfer of which will be done in accordance with applicable data protection law and this Agreement.
- 20.2 For the avoidance of doubt Parties may not process, sell, retain, use or disclose the Personal Data for any purpose other than for the specific purpose specified in this Agreement or as required or permitted by applicable data protection law. By signing this Agreement, Parties certify that they understand this condition and will comply with it. Each party is a data controller in respect of the Personal Data.
- 20.3 Personal Data processed by Shell is governed by the terms of the Privacy Notice - Business Customer, Supplier, Partner or Investors, available at <https://www.shell.com/privacy/b2b-notice.html>. and from the relevant Shell website in each location.

21 TAXATION

- 21.1 The Research Partner will be responsible for and indemnify Shell from all taxes, levies, social securities and other charges and duties imposed in connection with the provision of the services and the supply of goods and intangible property (referred to as "Tax").

21.2 All amounts invoiced by Research Partner will include all Taxes in connection with the provision of Study. GST, as applicable, or an equivalent GST that is due in connection with the supply of the Study, will be clearly identified separately on the invoice.

21.3 Shell may withhold any pay over to the relevant authorities Taxes from any payment that would otherwise be made by Shell to Research Partner to the extent that the withholding may be required by applicable Laws. Shell will provide Research Partner with tax receipts or other proof of payment for any Taxes withheld within 60 days after payment. Where the requirements for any withholding are avoided by Research Partner holding a valid exemption certificate, it is the duty of Research Partner to: (i) inform Shell on a timely basis of the certificate; and (ii) provide copies of the certificate or further information that may be required to avoid the withholding.

21.4 The Research Partner and Research Partner Personnel render the services under this Agreement as independent Party(ies) and is(are) not authorized to act as the agent or representative of Shell or to represent that it or they are entitled so to act. The Research Partner and Shell agree that no employment relationship shall exist between Shell or any Affiliates and Research Partner Personnel. The Research Partner will maintain complete control over and have full responsibility for the performance of its personnel, agents, consultants and subcontractors. Shell reserves no right to direct, supervise or control the operations, personnel, agents, consultants or Subcontractors of the Research Partner. Accordingly, the Research Partner and Shell agree as follows:

- (a) The Research Partner shall be responsible for ensuring that all wages, fees, contributions and all social security and other contributions including for the avoidance of doubt National insurance contributions, charges and taxes required to be paid by the Research Partner in respect of Research Partner Personnel are paid, together with any payments due or in respect of any Generally Embargoed Country (GEC) personnel required by law; and
- (b) The Research Partner shall ensure that all appropriate deductions are made from the wages of the Research Partner's Personnel in respect of taxes, employees social security and other contributions including for the avoidance of doubt national insurance contributions.

21.5 The Research Partner is fully responsible for its personnel and the Research Partner vis-à-vis Shell assumes full and exclusive liability for payments of claims for salaries, benefits, indemnities and other demands related to the employment, that are made by Research Partner Personnel, or their dependants or successors. Neither the Research Partner nor Research Partner Personnel shall be deemed to be either expressly or implicitly employees of Shell. Should it ever be determined that the Research Partner or Research Partner Personnel acted under this Agreement as an employee or co-employee of Shell and/or its parent(s), affiliates and subsidiary companies, then to the maximum extent permitted by law, the Research Partner shall defend, indemnify and hold harmless Shell, its parent(s), affiliates, and subsidiary companies against (i) any loss, damage, claim, suit, liability, judgment and expense (including, but not limited to, attorneys' fees and other costs of litigation), (ii) any fines, penalties, or assessments, arising out of any such determination, and (iii) any claim of coverage or eligibility under any of the compensation arrangements or benefit plans of Shell and/or its parent(s), affiliates and subsidiary companies.

22 ASSIGNMENT AND SUB-CONTRACTING

22.1 The Research Partner shall not assign all or any of its rights or obligations under this Agreement.

22.2 Shell may at any time assign all or any part of the benefit of, or its rights or benefits and/or obligations under this Agreement. Shell shall be free to arrange for any of its obligations and/or rights under this Agreement to be performed or exercised respectively by one or more Affiliates of Shell and/or other third parties.

23 AMENDMENTS AND VARIATIONS

This Agreement may not be amended or modified orally and no amendment or modification shall be effective unless it is in writing and signed by the authorised representatives of each of the Parties.

24 LAW AND JURISDICTION

24.1 Governing Law

This Agreement, and any dispute or claim arising out of or in connection with this Agreement or its subject matter or formation, including any non-contractual disputes or claims, will be exclusively governed by and construed in accordance with the laws of India, excluding conflict of law rules and choice of law principles that provide otherwise. The United Nations Convention on the International Sale of Goods will not apply to this Agreement.

24.2 Dispute Resolution

- (a) Any dispute or claim arising out of or in connection with the Agreement or its subject matter or formation, whether in tort, contract, under statute, or otherwise, including any question regarding its existence, validity, interpretation, breach, or termination, and including any non-contractual claim, will be finally and exclusively resolved by arbitration as per Arbitration and Conciliation Act, 1996 under the then prevailing arbitration proceedings rules of the Delhi International Arbitration Centre.
- (b) The arbitral tribunal, to be appointed in accordance with the arbitration rules, will consist of one arbitrator. However, if either party asserts the amount in controversy exceeds USD \$5 million, then the tribunal will consist of three arbitrators.
- (c) The seat of the arbitration will be New Delhi, India.
- (d) The language of the arbitration will be English.
- (e) The International Bar Association Rules on the Taking of Evidence in International Arbitration will apply to the arbitration.
- (f) Each party waives, to the fullest extent permitted by law, any right under the laws of any jurisdiction:
 - i) to apply to any court or other judicial authority to determine any preliminary point of law; and
 - ii) to appeal or otherwise challenge the award, other than on the same grounds on which recognition and enforcement of an award may be refused under Article V of the United Nations Convention on the Recognition and Enforcement of Foreign Arbitral Awards of 1958 ("The New York Convention").
- (g) Nothing in this Article will be construed as preventing any party from seeking conservatory or similar interim relief from any court with competent jurisdiction. Any award rendered by the arbitral tribunal will be made in writing and will be final and binding on the parties. The parties will carry out the award without delay. Judgment upon any award or order may be entered in any court having jurisdiction. All aspects of the arbitration will be considered confidential.

25 MISCELLANEOUS

- 25.1 Research Partner and its Related Parties shall not prepare photographs, articles, press releases or speeches about the existence of, study, or work to be performed hereunder, or any details about Shell's facilities or business plans without prior written consent from Shell.
- 25.2 Failure or delay by Shell in enforcing or partially enforcing any provision of the Agreement shall not be construed as a waiver of any of its rights under the Agreement.
- 25.3 Any waiver by Shell of any breach of, or any default under, any provision of the Agreement by Research Partner shall not be deemed a waiver of any subsequent breach or default and shall in no way affect the other terms of the Agreement.
- 25.4 The rights and remedies provided by the Agreement are cumulative and not exclusive of any rights or remedies provided in law, equity, or otherwise and shall extend to Shell's successors and assigns.
- 25.5 This Agreement, and all ancillary notices, correspondence, and other documents, will be in English. Where translations have been provided, the English version will prevail in case of any conflicts or inconsistencies between translations.
- 25.6 If any provision of the Agreement is determined invalid or unenforceable in any respect, the provision will remain enforceable in all other respects and all other provisions of the Agreement will be given full effect.
- 25.7 This Agreement may be executed and delivered by the parties in counterparts (each of which shall be considered for all purposes an original) and when a counterpart has been executed and delivered by each of the parties, all such counterparts shall together constitute one agreement.
- 25.8** If requested by Shell, Research Partner agrees to use Shell's designated on-line tool to sign with a digital signature, except where prohibited by applicable law. If signed digitally, Shell and Research Partner agree to waive any right to dispute the genuineness of the signature, or the admissibility of the Agreement where such challenge is based on the absence of a physical signature.
- 25.9 The covenants, conditions and provisions contained in the Agreement which the parties intend to survive, including confidentiality obligations, intellectual property rights and liabilities, audit rights, warranties, applicable law, dispute resolution, and indemnities, survive termination and expiry of the Agreement for the benefit of the party or parties to whom they are given. In addition, the expiry or termination of the Agreement does not discharge or release either party from any liability or obligation accrued at the time of such expiry or termination or continuing beyond or arising out of such expiry or termination.
- 25.10 This Agreement constitutes the entire agreement between the parties hereto. No amendments to the Agreement, nor any contrary or additional conditions specified by Research Partner in any document provided by Research Partner, shall be effective unless evidenced in writing and signed by the parties hereto.
- 25.11 In the case of any conflict between the terms of the Appendices and this Agreement, the terms of this Agreement shall prevail.
- 25.12 The concept of severability of clauses applies.

AS WITNESS WHEREOF, the Parties have caused this Agreement to be executed in duplicate original at the places and on the dates specified below.

For and on behalf of **Shell**

Signature:
.....

By:
.....

Title:
.....

Place:
.....

Date:

For and on behalf of **Research Partner**

Signature:

By:

Title:

Place:

Date:

APPENDIX I

THE STUDY

Project title: A novel utility to measure, optimize and reduce carbon footprint for software in computational and data science workflow.

Problem Statement:

In the digitalization space, running simulation software is one of the key elements for solving critical business problems. While we are approaching the “Exascale” era of supercomputing, the main bottleneck remains power consumption, estimated to be around 20 megawatts. The rank one supercomputer in Top500 (June 2021), Fugaku, has 48 cores/socket. The upcoming Exascale systems would have nodes with more than twice the cores/sockets on Fugaku. Despite this massive parallelism, the Exascale systems are projected to consume 1.5 times less power than Fugaku. Modern multicore processors with massive parallelism have made achieving energy efficiency in parallel applications challenging.

Recently, Shell has formulated a new strategy to reduce its carbon footprint in different parts of its business, where it says – “Digitalisation alone will not solve world’s energy problem, but widespread adoption of digital technology will be one of the keys to achieving a net-zero future. Deep decarbonization of energy infrastructure and consumption will require a comprehensive digital transformation to be applied right across the energy value chain.”

Although Shell’s data centres are mostly carbon neutral or going to be carbon neutral in the coming years, the application of Artificial Intelligence (AI) is still very power-hungry. For example, the accuracy of any AI model which is being built at Shell (and outside) depends on large-scale training which itself is a compute intensive operation. This means that, for large-scale training networks, the usage of computational resources is heavy (consuming hours to days of computing time), which significantly impacts power utilization and carbon emission. The current research shows that state-of-the-art model training algorithms, using new technologies such as transformers, have a significantly high carbon footprint (see the figures below).

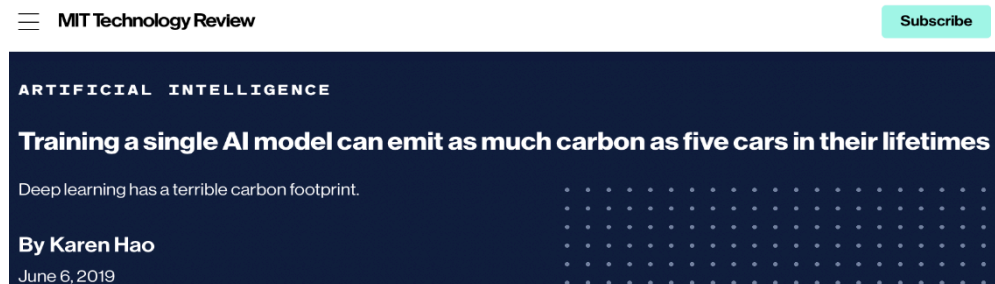


Figure 1: Carbon footprint of AI training model

(Source:

<https://www.technologyreview.com/2019/06/06/239031/training-a-single-ai-model-can-emit-as-much-carbon-as-five-cars-in-their-lifetimes/>)

Common carbon footprint benchmarks

in lbs of CO2 equivalent

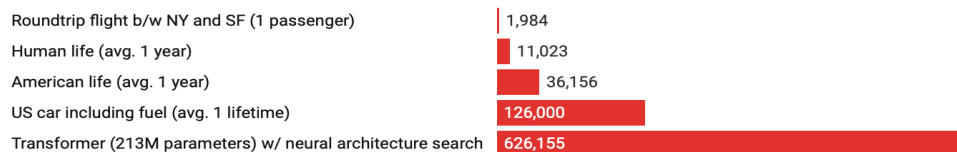


Chart: MIT Technology Review • Source: Strubell et al. • Created with Datawrapper

Figure 2: carbon footprint benchmarks

(source: <https://www.infoworld.com/article/3568680/is-the-carbon-footprint-of-ai-too-big.html>)

| | Date of original paper | Energy consumption (kWh) | Carbon footprint (lbs of CO2e) | Cloud compute cost (USD) |
|---|------------------------|--------------------------|--------------------------------|--------------------------|
| Transformer (65M parameters) | Jun, 2017 | 27 | 26 | \$41-\$140 |
| Transformer (213M parameters) | Jun, 2017 | 201 | 192 | \$289-\$981 |
| ELMo | Feb, 2018 | 275 | 262 | \$433-\$1,472 |
| BERT (110M parameters) | Oct, 2018 | 1,507 | 1,438 | \$3,751-\$12,571 |
| Transformer (213M parameters) w/ neural architecture search | Jan, 2019 | 656,347 | 626,155 | \$942,973-\$3,201,722 |
| GPT-2 | Feb, 2019 | - | - | \$12,902-\$43,008 |

Figure 3: The estimated costs of training an AI model once

(Source -

<https://www.technologyreview.com/2019/06/06/239031/training-a-single-ai-model-can-emit-as-much-carbon-as-five-cars-in-their-lifetimes/>)

Two initiatives are currently being pursued at Shell. However, both initiatives focus on the monitoring of energy usage and carbon emissions, leaving unaddressed gaps with respect to low-level monitoring of algorithms (e.g., FLOPs) or optimization of computing. The capabilities to perform such tasks have not yet been developed. The proposal herein aims to address these yet to be developed opportunities for improved energy efficiency in modern computing workflows which demands modern high performance.

Outside of Shell, there is a continuous effort in the computer industry to design better power/energy efficient computing systems¹ to complement the effort and to address the need to reduce energy requirements for simulations. Hence there is a need to design better energy-efficient software programs for next generation computing systems.

On the other hand, there is an increasing need to use portable and low-power equipment, like EDGE devices, to perform demanding computing operations. Typically, the power budget of such devices is about around 1 to 5 watts. Ultimately the question is how do we maximise the compute (flops) in smaller devices with a limited power budget?

While energy efficiency is becoming increasingly important, few software engineers still understand how coding styles affect the energy and power consumption of their programs. To enable developers to achieve energy savings, we must associate energy consumption with software structures, especially at the fine-grained level of algorithms and data structures.

This proposed work aims to 1) identify the energy consumption hotspots of an application in addition to monitoring and 2) measuring the power/energy usage (alternatively, CO2 consumption) of

¹ See the list of Green500 supercomputers (<http://www.green500.org>) for more details.

computationally demanding workloads. Once the energy consumption hotspots are pinpointed, the software engineers can focus their development on modifying the applications accordingly. One typical example of a hotspot in AI is the training part of any machine learning / deep learning algorithm. These tasks are computationally intensive. An additional contribution of this work aims to provide a runtime library that could automatically throttle the processor frequency for an energy-efficient execution of applications.

Once we have a framework and tool to measure the “carbon footprint” of simulation software, we can add that as an additional metric while doing the performance engineering and optimization. Instead of measuring FLOPS as the only metric we can then target FLOPS/watt to measure the energy efficiency of any software application without trading off the performance.

This proposal's key performance indicators (KPIs) are the measurement and reduction of carbon emissions and energy usage in a manner that does not compromise the overall performance of applications in Shell's digital world.

References

1. Luca Benini, Source Code Optimization and Profiling of Energy Consumption in Embedded Systems, Conference paper, 2020, [DOI: 10.1145/501790.501831](https://doi.org/10.1145/501790.501831)
2. Ehsan Ahvar, Anne-Cécile Orgerie, Adrien Lebre, Estimating Energy Consumption of Cloud, Fog and Edge Computing Infrastructures, INRIA, <https://hal.archives-ouvertes.fr/hal-02083080>. (2019)
3. Barzan Yosuf et al, Energy Efficient Service Distribution in Internet of Things, [DOI: 10.1109/ICTON.2018.8473659](https://doi.org/10.1109/ICTON.2018.8473659), Conference: International Conference on Transparent Optical Networks ICTON (2018)
4. Adrian Carrio et al, A Review of Deep Learning Methods and Applications for Unmanned Aerial Vehicles, <https://doi.org/10.1155/2017/3296874>, Journal of Sensors, Volume 2017, Article ID 3296874 (2017)
5. Shijin Zhang et al, Cambricon-X: An Accelerator for Sparse Neural Networks, [DOI: 10.1109/MICRO.2016.7783723](https://doi.org/10.1109/MICRO.2016.7783723), 49th Annual IEEE/ACM International Symposium on Microarchitecture (MICRO) (2016)
6. Lev Mukhanov et. al., [ALEA](https://doi.org/10.1145/3050436): A Fine-Grained Energy Profiling Tool, DOI <https://doi.org/10.1145/3050436> ;
7. Vivek Kumar et al, Cuttlefish: Library for Achieving Energy Efficiency in Multicore Parallel Programs, SC'21

Proposed solution

We intend to build a customized framework using open-source tools. The solution will have two components. The first component will be the energy profiling the measurement tool based on technologies like Dynamic Voltage and Frequency Scaling (DVFS) and Uncore Frequency Scaling (UFS).

The high-level architecture of our proposed framework is shown in Figure 4. The framework consists of the Online Energy Profiler (OEP) and the CuttlefishML runtime to improve the ML application's energy efficiency for a multicore processor. The proposed methodology will use the statistics generated from OEP and thus transparently achieve energy efficiency using a variety of control knobs, such as DVFS, UFS, Dynamic Duty-Cycle Modulation (DDCM), and Power Capping (PCAP).

Our tool will support both C/C++ and Python-based applications. Users of the tool will have to insert two APIs in their application around the region requiring energy profiling or improved energy efficiency.

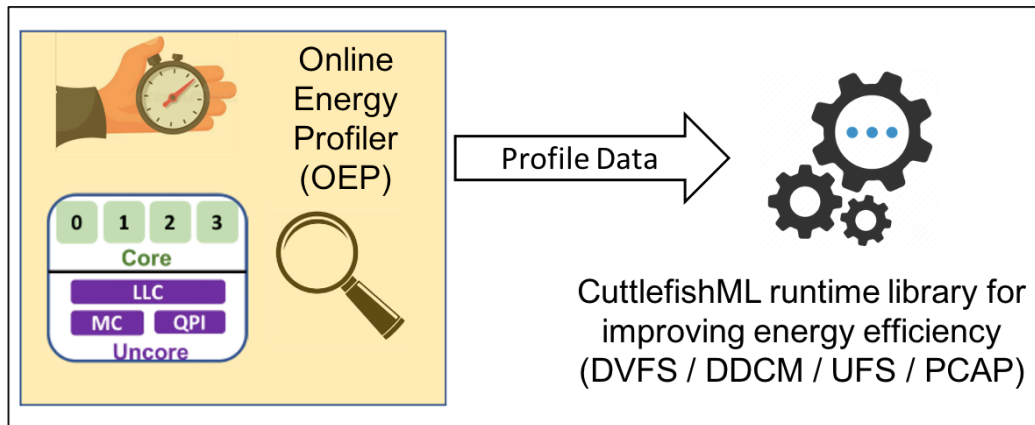


Figure 4: Architecture of the proposed workflow

This project will also extend the existing work from the ML & energy project ². This 2021 AI innovation project created a simple-to-use Python interface to measure energy usage of AI applications developed by Shell data scientists. Updates to the ML & Energy library include additional reporting features at lower levels of functions and algorithms (e.g., FLOPs) and furthermore incorporate new capabilities to optimize computing.

Planned Delivery timelines and pivot points:

| Phase | Delivery Date |
|--|---|
| Framework & Experiment Design – part 1 <ul style="list-style-type: none"> Draft methodology/code design to implement online energy profiler (OEP) with GUI interface for C/C++/Python | 3 months from the start date of the project |
| Implementation Phase – part 1 <ul style="list-style-type: none"> Implement OEP and develop the GUI as per design | End of Month 4 |
| Pilot Implementation Phase – part 1 <ul style="list-style-type: none"> Develop and implement the methodology (based on CuttlefishML) to reduce the frequency exploration space/time | End of Month 10 |
| Pilot Implementation Phase – part 2 <ul style="list-style-type: none"> Develop and implement an adaptive approach using a combination of DVFS and DDCM within CuttlefishML | End of Month 16 |
| Pilot Implementation Phase – part 3 <ul style="list-style-type: none"> Develop and implement an adaptive approach using a combination of DVFS and DDCM within CuttlefishML | End of Month 24 |
| User Testing & Feedback Phase (to be taken care of by Shell) <ul style="list-style-type: none"> Performance testing of the implementation and standardize the APIs; develop library module for global usage (Chiranjib) | 1-2 months (based on the implementation progress) |

² ML & energy project GitHub: <https://github.com/sede-x/ml-and-energy>

| | |
|--|---|
| <ul style="list-style-type: none"> ● Incorporate new library into existing Shellpowermeter library (NLP Team). <ul style="list-style-type: none"> i. Refactor Shellpowermeter library to read from new energy measurement library ii. Work with IRM to rollout updated changes on cloud iii. Test updated Shellpowermeter library (compare readings of existing energy measurement approach to new energy measurement approach) ● Test the solution for applications running in EDGE platforms and identify /quantify the power savings, | |
| Reporting Findings <ul style="list-style-type: none"> ● Intermittent internal reports ● Write-up of publication for submission at appropriate journal or conference on findings from experiments. (probably two in two phase – one the solution side and one with the definitive use cases) | <ol style="list-style-type: none"> 1. After month 6 2. After month 12 3. After month 18 4. After month 24 |

Technical Feasibility:

Here are some references about energy profiling tools used in the external world which are relevant to this proposal.

1. Lev Mukhanov et. al., [ALEA](https://doi.org/10.1145/3050436): A Fine-Grained Energy Profiling Tool, DOI <https://doi.org/10.1145/3050436> ;
2. Vivek Kumar et al, Cuttlefish: Library for Achieving Energy Efficiency in Multicore Parallel Programs, SC'21

We propose to develop the solution based on available frameworks like the above.

APPENDIX II

PAYMENT SCHEDULE

In full and final settlement for the performance of the Study, the production and issue of the Results, the granting of Rights, and for fulfilling and/or complying with all other terms and conditions of the agreement Shell shall pay to the Research Partner the total amount of USD 52800 (Excluding GST and Travel Expenses)

| Budget Head | Year 1 | Year 2 | Total |
|---------------------------------------|--------|--------|-------|
| Supercomputing charges (servers etc.) | 15000 | 0 | 15000 |
| Human resources (researchers) | 10000 | 8000 | 18000 |
| Consumables | 3000 | 2000 | 5000 |
| Travel | 2000 | 1500 | 3500 |
| Contingencies | 1500 | 1000 | 2500 |
| Total (A) | 31500 | 12500 | 44000 |
| Institute Overheads 20% (B) | 6300 | 2500 | 8800 |
| Total (A+B) | 37800 | 15000 | 52800 |

The above table is representative, and allocation to various heads may change depending on need while maintaining the total expenditure within USD 52800.

This amount shall be paid in two installments as agreed with Shell and Research Partner.

To the extent authorized, Shell shall reimburse all out-of-pocket travel and lodging expenses as part of the Study for Research Partner at actual cost (including, but not limited to, hotel, airfares and car rentals collectively “Travel Expenses”) provided that such Travel Expenses are documented with receipts and are attached to the invoice. Travel shall be at normal coach/economy class fares; overnight lodging shall be at rates comparable to standard economy room rates. Research Partner shall arrange alternatives to hotel expenses (e.g. apartment rentals, corporate housing, etc.) and local transportation (e.g. sharing of rental cars, etc.) to minimize lodging expenses where cost effective.

Travel expenses shall be invoiced together with each installment.