

**AIR QUALITY MONITORING AND CONTROL (AQMC)
FUNDING INITIATIVE (FI)**

REQUEST FOR PROPOSAL (RFP) ON DEVELOPING AN INTEGRATED LOW-COST AIR QUALITY SENSOR SYSTEM WITH STREET-LEVEL AIR QUALITY MODELLING CAPABILITIES TO IDENTIFY AND PREDICT AIR POLLUTION HOTSPOTS AND ITS CAUSAL FACTORS

Research Area	Development of Street-level Modelling Capabilities assimilating Low-Cost Sensors for Pollution Control
Publication Date	15 JUL 2024, 11.00am
Closing Date and Time	15 OCT 2024, 11.00 am
Proposal Submission	Applications shall be made via: Integrated Grants Management System (IGMS) at https://researchgrant.gov.sg by the closing date
Instructions and Format of Submission	Please refer to the following websites: https://www.nea.gov.sg/programmes-grants/grants-and-awards/research-innovation-and-enterprise-funding-initiatives/air-quality-monitoring-and-control-funding-initiative or via IGMS at https://researchgrant.gov.sg

AQMC FI

RFP ON DEVELOPING AN INTEGRATED LOW-COST AIR QUALITY SENSOR SYSTEM WITH STREET-LEVEL AIR QUALITY MODELLING CAPABILITIES TO IDENTIFY AND PREDICT AIR POLLUTION HOTSPOTS AND ITS CAUSAL FACTORS

Please refer to [Appendix 0](#) for the definition of *italicised terms* used in this RFP.

BACKGROUND

1. The National Environment Agency (NEA) operates 23 air quality monitoring stations across Singapore to continuously monitor the quality of ambient air. The monitoring stations provide measurements of key air pollutants over large areas, in a manner that meets United States Environmental Protection Agency's requirements for accuracy and reliability.
2. While useful in monitoring air quality at the national and district level, these measurements do not accurately represent the levels of pollutants over smaller areas such as within *residential estates* due to potential localised build-up of pollutants. Measurements of pollutants at higher spatial resolution could be obtained by deploying more air quality monitoring stations. However, scaling up these stations is not feasible as they require a large land footprint and incur a high operating cost.
3. NEA therefore also deploys air quality models to simulate the dispersal of pollutants to aid in the identification of air pollution episodes for subsequent action. However, the models currently available on the market face shortcomings such as low spatial resolution, only being able to ingest historical and emission data, high cost or proprietary, and require a long run-time which is suitable more for research instead of operational purposes.
4. *Low-cost air quality sensors* are an emerging technology that allows air quality to be measured in more locations at a lower cost. Data obtained from a network of such sensors could then be integrated with other historical or real-time data into an air quality model to monitor and even forecast the concentration of street-level pollutants on a local scale with higher spatial resolution. However, the accuracy and reliability of such sensors has yet to be proven over time in Singapore for airborne pollutants that NEA is interested in.
5. By assimilating data from *low-cost air quality sensors* and existing air quality monitoring stations as inputs into a high spatial resolution street-level model with fast run-time, NEA will be able to monitor the distribution of *key airborne pollutants* at street level, allowing us to identify the key factors affecting pollutant accumulation and movement, and project air quality at *sensitive receptors*. This will help inform the evaluation and implementation of potential pollution control policies to minimise exposure to air pollution in daily living.

SCOPE OF RFP

6. This RFP is an open call by NEA to solicit Research and Development (R&D) proposals to develop and fuse a system comprising street-level, high spatial resolution, fast run-time air quality model(s) assimilating *low-cost air quality sensors* for *key airborne pollutants*. The system is to be calibrated to local environmental conditions to produce an accurate projection of localised air quality in a *residential estate* in Singapore.

7. Applicants may submit one or more proposal(s) addressing the problem statement and desired outcomes.

Problem Statement: Developing an Integrated *Low-Cost Air Quality Sensor System* with Street-Level Air Quality Modelling Capabilities to Identify and Predict Air Pollution Hotspots and its Causal Factors

8. The study should achieve the desired outcomes below:

- a) Develop street-level air quality model(s) to predict air quality in areas which are beyond the sensing radius of sensors. The model(s) should assimilate real-time sensor data (see para 8b) to generate pollution concentration maps of a Singapore *residential estate* (e.g. Bukit Merah) with high spatial resolution of 10m or better. The model(s) should achieve a Coefficient of Determination (R^2) and Root Mean Square Error (RMSE) that are within 10% of the recommended sensor performance targets for respective *key airborne pollutants* (refer to [Appendix 1](#)) when compared to on-site sampling measurements using linear regression. Operational availability (expressed as a percentage of time for which data is available) should be $\geq 90\%$. The applicant may suggest performance targets above and beyond these minimum targets. The model(s) should also meet the following requirements:

	Required features	Proposals that will be rejected
Subsequent Modification/ Development	NEA and/or its agent/vendor are to be allowed to modify the system (e.g. to include other inputs/ factors into the model) and further develop the system beyond the current project scope post-project	System which cannot be modified by NEA and/or its agent/vendor to include other inputs/ factors post-project
Type of Data Inputs accepted into model(s)	System is to be able to utilise both historical & real-time data inputs	Systems that only utilise either historical or real-time data

Temporal Resolution	Model outputs must be at a temporal resolution of ≤ 1 hour	Model outputs that have a temporal resolution of > 1 hour
Spatial Resolution	Model outputs must be at a spatial resolution of $\leq 10\text{m}$	Model outputs that have a spatial resolution of $> 10\text{m}$
Height	Model outputs must include Street Level (approximately 1.5m from ground) datapoints	Model outputs are at Mid and/or High Altitudes only
Range of conditions to be modelled	System must be able to model for Day-to-day and High Concentration episodes	Systems that can model for either Day-to-day or high concentration episodes only
Pollutants to be modelled	System must be able to measure and model these six key <i>air pollutants</i> - PM2.5, PM10, NO ₂ , SO ₂ , O ₃ and CO	Systems that are not able to measure and model one or more key air pollutant.
Factors affecting pollution accumulation, to be modelled	System must be able to model for the following factors - Air dispersion around buildings, major types of activities generating <i>key air pollutants</i> (including point and diffuse area sources), meteorological conditions, traffic conditions, street canyon effects, buffer effect from vegetation cover and tree canopies	Systems that are not able to model one or more of the factors listed.
Processing speed	System is to have a maximum run-time of 3hr, preferably within 1hr per run-time	Systems with run-time above 3hr
Processing resources	System only requires typical office desktop computers, runs on local hardware only	Systems that require supercomputers, commercial cloud

- b) To act as inputs to the model(s) developed in para 8a, develop, test-bed and validate a *low-cost air quality sensor* network for measuring *key airborne pollutants* in real time. The sensors shall meet recommended performance targets (refer to [Appendix 1](#)), have a high temporal resolution i.e. sampling time interval of 1 hr or better, and require minimal maintenance

and manual calibration, ideally no more than once every 3 months. Applicants may utilise Commercial Off the Shelf (COTS) sensor products, where available and suitable, which can be improved to achieve the performance targets and resolution.

- c) The *low-cost air quality sensors* should be shortlisted based on available literature and/or experience regarding their suitability for local environmental conditions (e.g. humidity and temperature), and co-located with NEA's nearest ambient air quality monitoring station for calibration (performing sensor data correction as required), performance evaluation and selection for subsequent field deployment. The sensor network shall be evaluated for accuracy and reliability over a minimum 12-month field deployment.
- d) Analyse the data from the calibrated sensors (para 8b & c) and model (para 8a) to understand the different factors and *estate characteristics* affecting air quality and dispersion/accumulation of pollutants at *sensitive receptors*. Thereafter, to analyse the results (e.g. if pollutant levels have reached/exceeded threshold levels, how often, during which periods) and propose preliminary measures to mitigate residents' exposure to pollutants and reduce pollutants at the estate level.

9. A map of the suggested deployment location in Bukit Merah *residential estate* showing the estate boundaries, as well as potential sensor deployment locations is in Appendix 2. The number of *low-cost air quality sensors* to be deployed for sufficient coverage should be determined by the sensing radius of the developed sensor. For instance, assuming the developed sensors have a sensing radius of 500m, the Bukit Merah estate will require a network of *low-cost air quality sensors* to be deployed in approximately 10 locations for minimum coverage of the *sensitive receptors*. Meteorological sensors such as wind sensors to measure airflow velocity and direction within the estate should also be deployed where necessary. The applicant may propose (with justifications) the actual *residential estate* or area to be covered, sensor deployment locations, and number of sensors needed.

10. The proposed sensor network and integrated model should provide provision for any auxiliary services required to set up the network (e.g. Internet of Things (IoT) infrastructure, power supply, measures to prevent tampering/theft, data transmission to a server), data analysis and a platform for users to view and interpret the findings.

11. Applicants should develop an integrated solution which fully meets the desired outcomes of the study and are encouraged to collaborate with relevant expertise on a joint proposal which leverages cross-domain expertise to achieve this.

PROPOSAL REQUIREMENTS AND SUBMISSION

12. All Proposals shall be submitted through the IGMS before closing date. Applicants are to refer to the "Instructions and Templates for Applicants" for guidelines prior to submission of the proposal.

13. The Proposal(s) shall include but shall not be limited to the following information:

- a) Detailed description of the research objective, scope and proposed methodologies to achieve the desired outcomes. This may include, but not limited to, geographical information (i.e. maps) containing proposed *residential estates* to be studied, area of coverage by sensors and model(s), proposed locations of sensors, proposed calibration methods, testing and evaluation protocols, characteristics of identified estates which may impact the dispersion of air pollutants, rationale behind the proposed plan, and equipment to be used.
- b) Comparison of proposed research methodologies/methods with other available methods (if applicable).
- c) Detailed description of sensors/equipment/tools to be used for measuring air pollutants. This should include the specifications, accuracy and sensitivity of the equipment, laboratory and/or field test reports (if any) and reference to similar/relevant studies which used the equipment (if any).
- d) Detailed description of air quality model(s). This should include reasons for selecting the particular model(s); areas where model is to be adapted for this project(if any); main equations/processes; key model assumptions; how the model parameters were estimated/derived; key inputs and outputs; details of calibration and evaluation with calibration data and independent data; description of the approach taken to the uncertainty analysis and to the sensitivity analysis, and the results of these analyses; Quality Assurance (QA)/Quality Check procedures adopted or to be adopted; findings of QA by experts not involved in the model development (if any); interpretation of model results; references to peer-reviewed literature (where details of the research on the model can be found) (adapted from '2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 6: QA/QC and Verification').
- e) Project deliverables and timeline showing the milestones to be achieved and how the achievement of these milestones is determined.
- f) Proposed budget with justifications. Estimated costs of sensor system and dispersion model for full deployment at the selected *residential estate* (include capital and operating costs, with breakdown of line items), as well as how the systems and IP developed could be exploited for further translation and deployment for value capture, including quantification of impact beyond the immediate project.
- g) Research team, their capabilities and relevance of project team members.
- h) Indication of all in-kind services, funding, and tangible contributions by industry partners, host institute or any other partners towards the proposed project. In-

kind services include labour, materials, and other services such as loaning of facilities and space.

14. Requests for any data from Public Sector Agencies are to be submitted in the proposal (Research Proposal Template Section 4. Research Proposal - Data Requirements).

15. The Research Proposal Template may be found under section 1.7 of the IGMS project application form.

PROJECT DURATION AND SCHEDULE

16. The project duration shall not exceed 30 months, from initiation through to the completion of the project.

17. The proposed project schedule shall include major milestones and phases. The proposal shall also explain how the achievement of the major milestones and phases are to be evaluated and determined.

ELIGIBILITY AND FUNDING SUPPORT

18. This RFP is extended to all Institutes of Higher Learning (IHLs), research institutes, and private entities. The RFP is to support R&D work carried out in Singapore.

19. Funding support for each Research Proposal awarded shall be capped at a quantum of up to S\$2.4 million.

20. The funding support for successful proposers is indicated below:

Applicant – Nature of Organisation	Funding Support
Institutes of Higher Learning/Research Institutes	Up to 100% of qualifying project cost
Singapore Small and Medium Enterprises (SMEs) Singapore Start-ups Singapore Not-for-profits	Up to 50% of qualifying project cost
Large Local Enterprises (LLEs) Non-Singapore private sector entities (including not-for-profits)	Up to 30% of qualifying project cost

21. Indirect costs will not be supported for all private sector entities (i.e. 0% of indirect costs will be provided).

22. Funding of private entities for research projects (of total project budget >\$500,000) and test-bedding/demonstration/scale-up projects (of total project budget >\$2M) is conditional on collaboration with public sector performer. Funding for non-Singapore entities is conditional on the appointment of a Singapore Technology

Licensing Officer (STLO). More details are in Annex D of “Instructions and Templates for Applicants” document.

23. Private sector entities are to fill in the ‘declaration form for Private Sector Applicant(s)’ in Annex E of “Instructions and Templates for Applicants” document, and submit them via IGMS.

EVALUATION CRITERIA

24. Proposals will be evaluated against the following criteria:

S/N	Evaluation Criterion	Weightage (%)
1	Effectiveness in achieving desired outcomes • Relevance and completeness of proposed scope • Soundness and innovativeness of proposed methodologies • Quality and quantity of data to be collected	40
2	Ability for successful project implementation • Cost-effectiveness and reasonableness of proposed budget, relative to scope of study • Clarity of proposed milestones, deliverables and implementation schedule • Track record and relevant R&D capabilities/ expertise of Principal Investigator(s) and collaborators	35
3	Feasibility of post-project translation and impact • Partners and frameworks to enable translation and value capture for Singapore • Quantitative / Qualitative Impact beyond immediate study	25
Total Score		100

CONTACT

25. Please contact the Secretariat at [AQMC Grant Secretariat@nea.gov.sg](mailto:AQMC_Grant_Secretariat@nea.gov.sg), should you have any query.
26. Applicants shall refer to the Instructions and Templates for Applicants document on the Integrated Grants Management System (IGMS) at <https://researchgrant.gov.sg> as the primary source of information. Information is also available at <https://www.nea.gov.sg/programmes-grants/grants-and-awards/research-innovation-and-enterprise-funding-initiatives/air-quality-monitoring-and-control-funding-initiative>.
27. For companies that do not have company accounts in IGMS, please provide the details and information (per Annex F of “Instructions and Templates for Applicants” document) to the above contact point for account registration early. Account creation may take 5 to 10 working days and late applications due to delay in account registration will not be entertained.
28. Successful proposals will be notified in writing.
29. Applicants may refer to Annex G of “Instructions and Templates for Applicants” document for a check-list of documents to prepare.

APPENDIX 0 – TERMS AND DEFINITIONS

For this RFP, the following terminology applies:

- i. *Low-cost air quality sensors* – portable individual sensors capable of providing quick or instant detection of air pollutants of interest, and which typically cost between US\$150 – US\$2500¹ per pollutant measured in a sensor unit.
- ii. *Key Airborne Pollutants* – minimally PM2.5, PM10, NO₂, SO₂, O₃ and CO.
- iii. *Residential estate* – a geographical location containing buildings predominantly used for housing e.g. detached house, semi-detached house, terrace house, townhouse, apartment, condominium, or cluster housing unit.
- iv. *Estate characteristics* – these include but are not limited to: maturity of estate, design of buildings (orientation/height), location of artificial buffers (e.g. Multi-Story Carparks), location of sensitive receptors.
- v. *Sensitive receptors* – Places where the public, in particular vulnerable groups such seniors and children, may spend prolong periods of time in and therefore increase their exposure to airborne pollutants. These include but are not limited to: schools, hospitals, senior/child care centres, community centres etc.

¹ With reference to The Enhanced Air Sensor Guidebook (pg 50) by the United States Environmental Protection Agency (US EPA), and list of Gas-Phase and PM sensors evaluated by the US South Coast Air Quality Management District's Air Quality-Sensor Performance Evaluation Center (AQ-SPEC)

APPENDIX 1 – PERFORMANCE TARGETS FOR LOW-COST AIR QUALITY SENSORS

Pollutant	Metrics	Reference
PM2.5	Concentration Resolution: 1 $\mu\text{g}/\text{m}^3$ Standard Deviation (SD): $\leq 5 \mu\text{g}/\text{m}^3$ OR Coefficient of Variation (CV): $\leq 30\%$ Slope: 1.0 ± 0.35 Intercept (b): $-5 \leq b \leq 5 \mu\text{g}/\text{m}^3$ Coefficient of Determination (R^2): ≥ 0.70 Root Mean Square Error (RMSE) or Normalised Root Mean Square Error (NRMSE): RMSE $\leq 7 \mu\text{g}/\text{m}^3$ or NRMSE $\leq 30\%$	US EPA Performance Testing Protocols, Metrics, and Target Values for Fine Particulate Matter Air Sensors, EPA/600/R-20/280.
O ₃	Concentration Resolution: 1ppbv Standard Deviation (SD): $\leq 5 \text{ ppbv}$ OR Coefficient of Variation (CV): $\leq 30\%$ Slope: 1.0 ± 0.2 Intercept (b): $-5 \leq b \leq 5 \text{ ppbv}$ Coefficient of Determination (R^2): ≥ 0.80 Root Mean Square Error (RMSE): $\leq 5 \text{ ppbv}$	US EPA Performance Testing Protocols, Metrics, and Target Values for Ozone Air Sensors, EPA/600/R-20/279.
PM10	Concentration Resolution: 1 $\mu\text{g}/\text{m}^3$ Standard Deviation (SD): $\leq 5 \mu\text{g}/\text{m}^3$ OR	US EPA PM10 Supplement to the 2021 Report on Performance Testing Protocols, Metrics, and Target Values for Fine Particulate Matter Air Sensors, EPA/600/R-23/145

	Coefficient of Variation (CV): $\leq 30\%$ Slope: 1.0 ± 0.35 Intercept (b): $-10 \leq b \leq 10$ $\mu\text{g}/\text{m}^3$ Coefficient of Determination (R^2): ≥ 0.70 Root Mean Square Error (RMSE) or Normalised Root Mean Square Error (NRMSE): $\text{RMSE} \leq 14 \mu\text{g}/\text{m}^3$ or $\text{NRMSE} \leq 30\%$	
NO ₂	Concentration Resolution: 1ppbv Standard Deviation (SD): ≤ 5 ppbv OR Coefficient of Variation (CV): $\leq 30\%$ Slope: 1.0 ± 0.35 Intercept (b): $-5 \leq b \leq 5$ ppbv Coefficient of Determination (R^2): ≥ 0.70 Root Mean Square Error (RMSE): ≤ 15 ppbv	US EPA NO ₂ , CO, and SO ₂ Supplement to the 2021 Report on Performance Testing Protocols, Metrics, and Target Values for Ozone Air Sensors, EPA/600/R-23/146
SO ₂	Concentration Resolution: 1ppbv Standard Deviation (SD): ≤ 0.02 ppmv OR Coefficient of Variation (CV): $\leq 30\%$ Slope: 1.0 ± 0.2 Intercept (b): $-0.05 \leq b \leq 0.05$ ppmv Coefficient of Determination (R^2): ≥ 0.80	US EPA NO ₂ , CO, and SO ₂ Supplement to the 2021 Report on Performance Testing Protocols, Metrics, and Target Values for Ozone Air Sensors, EPA/600/R-23/146

	Root Mean Square Error (RMSE): ≤ 0.15 ppmv	
CO	Concentration Resolution: 1ppbv Standard Deviation (SD): ≤ 5 ppbv OR Coefficient of Variation (CV): $\leq 30\%$ Slope: 1.0 ± 0.35 Intercept (b): $-5 \leq b \leq 5$ ppbv Coefficient of Determination (R^2): ≥ 0.70 Root Mean Square Error (RMSE): ≤ 15 ppbv	US EPA NO ₂ , CO, and SO ₂ Supplement to the 2021 Report on Performance Testing Protocols, Metrics, and Target Values for Ozone Air Sensors, EPA/600/R-23/146

APPENDIX 2 – MAP OF SUGGESTED RESIDENTIAL ESTATE (BUKIT MERAH)



Source : SLA OneMap