

Smartphone Thermal Response to Concrete and Vegetated Surfaces: A Proof-of-Concept Pilot Study

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ACTIVE THERMAL MAPPING

Using Smartphones as Surface-Coupled Thermal Probes

Smartphone Thermal Response to Concrete and Vegetated Surfaces: A Proof-of-Concept Pilot Study

A preliminary investigation of surface-coupled device temperature response under contrasting environmental conditions

Working concept introduced in this study: "Hardware Heat Tax"

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Study type: **Independent pilot research**

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Status

This manuscript describes a *proof-of-concept* pilot study, submitted to [EarthArXiv](https://eartharxiv.org/) as a non-peer-reviewed preprint. The smartphone thermal response measurements described in Section 12 (eight paired observations) are transcribed directly from the author's laboratory notebook of 25 February 2026. Simultaneous thermometer-*versus*-phone calibration and repeated-trial replication are works in progress (Section 15). Any estimated or illustrative values are clearly identified as such and should not be taken as findings from a completed experiment. Accordingly, the findings and interpretations presented here should be considered as provisional rather than concluded.

Table of Contents

Abstract	3
1. Introduction	4
2. Research Question	4
3. Objectives	4
4. Working Hypotheses	5
5. Scientific Background	6
6. Conceptual Model	7
7. Materials and Experimental Method	8
8. Surface Temperature Reference Measurements	9
9. Smartphone–Thermometer Calibration	10
10. Important Distinction: Observed vs. Estimated Data	11
11. Device Thermal-Response Metrics: ΔT and STRI	11
12. Pilot Findings	12
13. The Hardware Heat Tax Concept	14
14. Major Limitations	15
15. Improved Experimental Design	17
16. A Better Measurement Framework	18
17. Potential Data Analysis	18
18. Why the Project Could Be Useful	19
19. Future Research Questions	20
20. Conclusion	20
21. Data Availability Statement	21
22. Ethics and Safety Statement	21
23. Conflict of Interest Statement	21
24. Author Contributions	21
25. Suggested Research Vocabulary	21
26. Related Work and References	22
27. Supplementary Material (Appendix)	25

Abstract

Urban heat is traditionally investigated from the outside in, through satellite imagery of surface patterns across an area, weather station observations of ambient air at a point, or surface-temperature measurements taken on the spot. This pilot study takes a different approach, asking what a heated surface does to a set of electronics being exposed to it, namely via ordinary smartphones as surface-coupled thermal probes. I am dubbing this method Active Thermal Mapping.

For this proof-of-concept investigation, two smartphones with distinctly different internal thermal engineering — one with a vapor-cooling apparatus (Phone 1), and one without (Phone 2) — were placed directly on a concrete surface and on grassy ground, in turn and in two separate trials (one trial in the early afternoon, and one in the evening of 25 February 2026). Both devices registered a considerably higher warming effect on the concrete than on grass during the daytime trials (ΔT of +9.9 °C and +11.4 °C on concrete vs. +4.5 °C and +5.1 °C on grass, for Phone 1 and Phone 2 respectively). In the evening, both devices registered a value warmer than their baseline on the concrete (+2.8 °C and +4.2 °C) but cooler than their baseline on grass some ninety minutes later (−3.3 °C and −2.9 °C). The device without active cooling (Phone 2) had a higher thermal response in all four matched conditions than the vapor-cooled device (Phone 1). A normalized Smartphone Thermal Response Index (STRI) was also calculated for purposes of cross-trial comparison (Section 12).

These eight paired data points represent an exploratory pilot rather than a controlled experiment: the two surfaces were not sampled simultaneously within a given day, only one trial was performed per condition per device, and a phone's internal sensor cannot serve as a valid proxy for surface temperature. The immediate priority for additional research (Section 15) is to perform repeated trials with simultaneous surface-temperature assessment and independent sampling, in order to properly calibrate a device's thermal response and evaluate it as a potential estimator for surface conditions.

1. Introduction

Urbanization replaces a lot of a city's vegetated surfaces with concrete and asphalt. These materials absorb heat during the day and release it at night, creating what is known as the Urban Heat Island effect. Other surfaces, such as vegetation, have different properties which cause them to absorb and release heat differently, and thus have an effect on the heat balance of the ecosystem they are a part of.

Thermal mapping from satellites and weather stations usually takes place from a third person's perspective. One is looking at the object from outside and measuring either the infrared light emanating from it, as one does when using a satellite, or the ambient air temperature, as one would do when using a weather station. In this project, however, one has to think about what happens to the electronics from the perspective of the object itself, the heated surface. A smartphone is not a precision tool, and while it could be used to estimate the temperature of the surface that it is on, it is not designed to do so. The temperature of the phone would depend on the thermal conductivity of the surface, the amount of heat generated by the hardware, any losses due to radiation, the ambient air temperature, and the phone's internal design.

However, the fact that it is not a precision tool is precisely the thing that can be used for this particular task. Instead of using the phone as a measuring device, an approximation of the relationship between the phone's temperature and the temperature of the surface can be created and used for this experiment.

2. Research Question

Primary Research Question

Can the temperature response of a smartphone placed directly on a surface serve as a simple, repeatable proxy for the thermal stress that surface imposes on the device?

Secondary Questions

- Does concrete produce a greater device-temperature increase than vegetation?
- Does this difference persist into the evening?
- Do different smartphone thermal architectures respond differently to the same surface?
- How strongly does smartphone temperature correspond to independently measured surface temperature? *This question is exploratory: the paired calibration dataset available for this pilot is still limited (Sections 8–10).*

3. Objectives

- 1: Compare the thermal properties of concrete and natural grass.
- 2: Check whether any thermal activity persists on concrete after sunset.
- 3: Compare the thermal-response characteristics of two smartphones that differ in their thermal designs.
- 4: Develop a simplified, normalized index — the Smartphone Thermal Response Index (STRI) — for comparative analysis of devices' surface-heating characteristics.
- 5: Identify the calibration, control, and statistical improvements needed for the next stage of this pilot study.

4. Working Hypotheses

Each hypothesis below is followed by its pilot status against the eight paired pilot observations reported in Section 12. With one trial per condition per device, these statuses describe a consistent pattern with a single pilot run — not a statistically confirmed effect yet.

H1: Concrete will produce a larger positive device-temperature response than grass under comparable conditions.

***Pilot status:** Consistent with the daytime pilot data (Section 12.1): both phones showed a substantially larger ΔT on concrete than on grass. The two surfaces were not measured simultaneously, so this is not a fully controlled comparison (Section 14).*

H2: Concrete will keep producing a positive thermal response into the evening, driven by heat storage and its gradual release.

***Pilot status:** Consistent with the evening pilot data (Section 12.2): both phones remained above baseline on concrete at ~7:00 PM. The heat-storage mechanism itself has not been isolated from other explanations (Section 12.2).*

H3: Smartphones with different internal thermal designs will display different responses under the same given surface conditions.

***Pilot status:** Consistent with the pilot data (Section 12.3): the device without a cooling feature (Phone 2) showed a larger ΔT than the vapor-cooled device (Phone 1) in all four matched conditions. With $n = 1$ device of each type, this remains exploratory.*

H4: Vegetated ground may produce a smaller, or even negative, response relative to the indoor baseline around at evening conditions.

***Pilot status:** Consistent with the pilot data (Section 12.2): both phones read below their own baseline on grass at ~8:30 PM.*

H5 (exploratory): Smartphone temperature response will show a measurable relationship with independently measured surface temperature.

***Pilot status:** Not yet tested. The four thermometer readings in Section 8 were not collected at the same times as the smartphone trials in Section 12, so no paired surface–device dataset exists yet (Section 10). This remains the central goal of this experiment (Section 15, Phase A).*

5. Scientific Background

5.1 Conduction

When the phone is in contact with a surface, heat will distribute itself across the area of contact when there is a temperature difference. This is the main mechanism the original experiment was concerned with.

5.2 Convection

The phone exchanges heat with the surrounding medium, and thus wind and the air temperature can contribute independently to temperature differences.

5.3 Radiation

A phone left in the sun may absorb short-wave radiation and subsequently emit some portion of this as thermal infrared energy. As such, a daytime measurement in the sun cannot be purely a conduction experiment.

5.4 Thermal Conductivity

Materials are unequal in terms of their abilities to conduct heat away from the point of contact, though this property alone will not determine the theoretical maximum temperature of the surface material.

5.5 Heat Capacity and Thermal Inertia

Materials can store heat and release it gradually, which explains the gradual increase in temperature measured over concrete in the evening. Both vegetation and concrete tend to exhibit this thermal storage inertia.

5.6 Vegetation and Evapo-transpiration

Vegetated surfaces lose heat energy to evaporation and transpiration and are shaded from solar forcing. Both effects are important mechanisms in explaining why grass can be so different from concrete.

5.7 Sensor Response and Thermal Lag

The sensor in the phone means that heat must penetrate the phone casing from the contact surface before being able to warm the sensor. As such, the sensor reading will always display a lag from the true contact surface temperature and will be a function of time-differential response:

$$T_d(t) \approx f[T_s(t - \tau)]$$

The thermal-response delay τ has not been estimated in this pilot. It is proposed as a physical consideration that the protocol (Section 15, Phase B) proposes to estimate empirically by recording temperature every minute rather than at a single 10-min point.

5.8 Proxy Measurement

The phone reading should be regarded as a proxy for the thermal response of the device, not the measured surface temperature.

5.9 Contact Resistance

Heat is not transferred from a surface to a phone sensor in a single step. There are multiple resistive thermal interfaces in series between the surface and the sensor: surface to back panel, back panel to internal chassis, and chassis to surrounding circuitry. Two phones on the same patch of concrete are not guaranteed to reach the same internal temperature, because the materials and configurations of their casings and internal structures will affect the conductive coupling at each interface. This provides a physical explanation for the device-to-device variability seen in Section 12.4, rather than assuming it is measurement error.

5.10 Notation

To avoid using the single word "temperature" for several physically distinct quantities, this manuscript uses the following symbols from this point forward:

Symbol	Meaning
T_s	Surface temperature, measured independently (e.g., by thermometer)
T_d	Device (smartphone) internal temperature
T_a	Ambient air temperature
T_b	Device baseline temperature (indoor, pre-exposure)

6. Conceptual Model

The proposed system can be sketched as the following simple chain:

surface → contact interface → phone chassis → internal components → temperature sensor.

But the phone has other thermal pathways running at the same time: sunlight striking the phone directly, heat exchanged with the surrounding air, and heat generated internally by the device's own electronics. Figure 1 lays these pathways out.

Conceptual Model: Pathways Contributing to Measured Phone Temperature

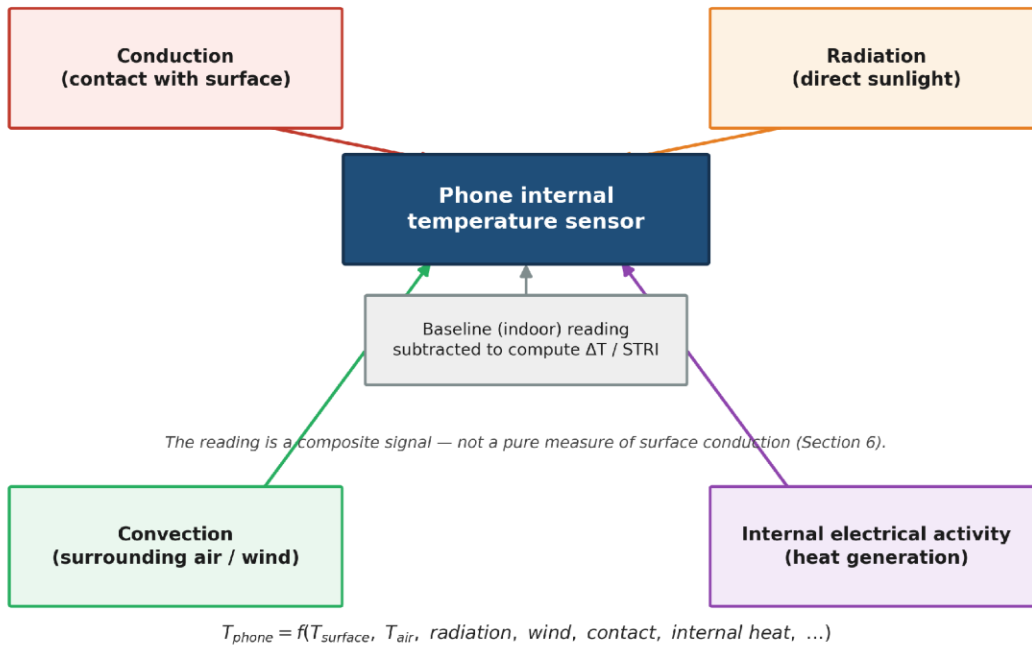


Figure 1. Pathways that contribute to a phone's measured internal temperature (Section 6).

In the notation of Section 5.10, the measured device temperature is a function of several inputs at once, not of surface temperature alone:

$$T_d = f(T_s, T_a, \text{radiation}, \text{wind}, \text{contact}, \text{internal heat generation}, \text{etc})$$

The experimental goal, then, is to control, or at minimum quantify, these extra contributions well enough that the surface signal stays visible and repeatable underneath them.

7. Materials and Experimental Method

The pilot trial described in this section was run on 25 February 2026 and is transcribed directly from the author's laboratory notebook; the raw entries are reproduced in full as Table S2 (Section 27).

7.1 Devices

Two smartphones were compared: Phone 1 (a device with a vapor-cooling thermal feature) and Phone 2 (a device with no dedicated cooling feature). Exact commercial models are withheld from this draft pending confirmation in the laboratory notebook; comparisons between the two devices in this manuscript refer to "Phone 1" and "Phone 2" rather than to price tier, since price and thermal architecture were not independently varied (Section 14).

7.2 Preparation

Protective cases were removed, airplane mode was enabled, and background applications were closed for both devices throughout the session. A shared baseline temperature was recorded for both phones at approximately 1:10 PM, immediately before the first (daytime concrete) exposure. Separate, freshly re-equilibrated baselines were recorded before each of the two evening trials (concrete ~7:00 PM; grass ~8:30 PM). This asymmetry — one shared daytime baseline versus two independent evening baselines — is carried into Section 14 as an explicit limitation, since it is not established that either phone had fully returned to its 1:09 PM baseline by the time of the 2:20 PM grass trial.

7.3 Test Surfaces

The pilot used exposed concrete (in direct/indirect sunlight, per trial) and natural grass/ground.

7.4 Exposure

Each device was placed directly on the selected surface for approximately 10 minutes, after which its internal temperature was recorded once. Four trials were run per device on 25 February 2026: concrete at 1:30 PM, grass at 2:20 PM, concrete again at approximately 7:00 PM, and grass again at approximately 8:30 PM (Section 12).

7.5 Control Variables to Improve

Future trials should record exact time, surface condition, weather, shade/sun status, phone orientation, contact area, contact pressure, starting temperature, exposure duration, wind, air temperature, and humidity — and each condition should be repeated several times, at matched or simultaneous times across surfaces, rather than measured once in sequence.

7.6 Experimental Variables

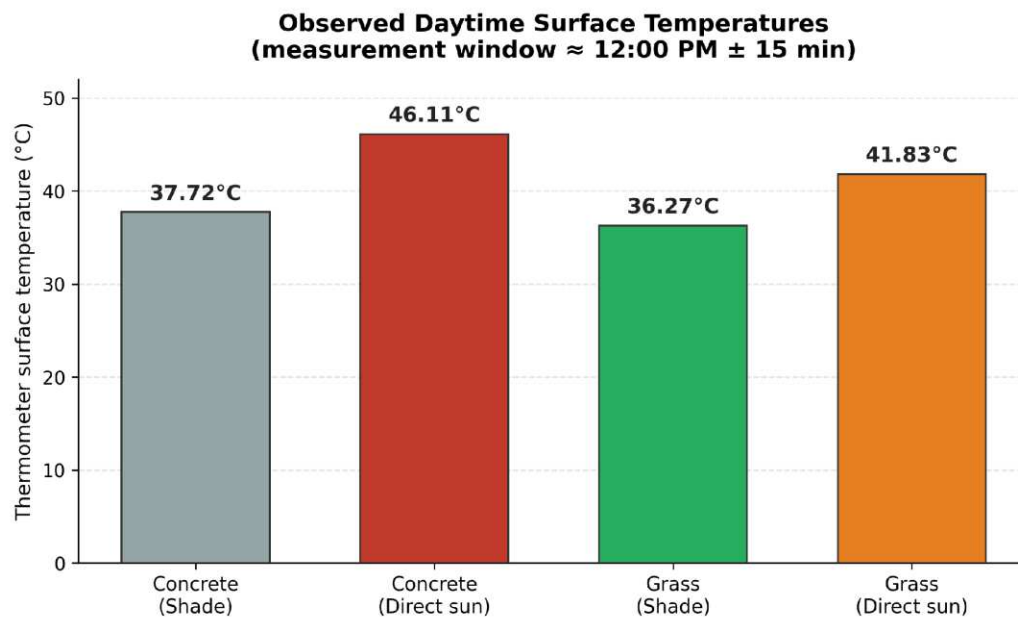
Stating the variables explicitly, in the notation of Section 5.10:

- **Independent variables:** surface type (concrete vs. grass), time of day (daytime vs. evening), and device type (Phone 1 vs. Phone 2).
- **Dependent variable:** device temperature change, ΔT_d (Section 11).
- **Secondary, normalized metric:** the Smartphone Thermal Response Index, STRI (Section 11).

8. Surface Temperature Reference Measurements

A later validation step, proposed by [Professor Manju Mohan](#), is to measure the actual surface temperature with a thermometer while also recording the phone's response simultaneously. The four readings below were collected independently of the smartphone trial in Section 12, on a different occasion and at a different time window (approximately 12:00 PM $\pm$ 15 minutes), rather than alongside it. They are reported here as a separate external reference dataset, not as calibration data for the Section 12 measurements (Section 10).

Surface	Condition	Thermometer Surface Temperature
Concrete	Shade	37.72 °C
Concrete	Direct sunlight	46.11 °C
Ground / grass	Shade	36.27 °C
Ground / grass	Direct sunlight	41.83 °C



Source: direct thermometer measurements reported in Section 8 (observed data, $n = 1$ reading per condition).

Figure 2. Observed daytime surface temperatures by surface and sun/shade condition (Section 8 data).

9. Smartphone–Thermometer Calibration

A significant methodological reality is that a phone’s internal temperature is not the surface temperature itself; the two should be expected to vary from one another, and the amount by which they deviate needs to be characterized rather than assumed.

The proper calibration experiment pairs a thermometer’s surface-temperature reading with the phone’s internal temperature at the same exposure time, with multiple readings taken at varying conditions. Plotting the phone’s temperature as a function of the surface temperature shows whether the relationship is approximately linear. If it is, a calibration model of the following form could be tested:

$$T_s = a \times T_d + b$$

The coefficients a and b have to be determined from real measurements; they cannot be chosen arbitrarily. If the relationship varied significantly between different phones, or between shaded and sunny conditions, a single universal correction would not be possible. The point of this exercise is not to make the phone and the thermometer agree, but to see whether the relationship is stable enough across conditions that the phone measurement has any value as a proxy at all.

This calibration has not yet been run: the surface-thermometer readings (Section 8) and the smartphone readings (Section 12) were collected on different occasions rather than at the same place and moment. Running this pairing properly is the specific purpose of Phase A in this experiment (Section 15).

10. Important Distinction: Observed vs. Estimated Data

This manuscript now draws on two separate observed datasets, and it is important not to blur them together:

- **Dataset A — smartphone thermal response** (Section 12): eight paired baseline/exposed temperature observations, transcribed directly from the author’s laboratory notebook of 25 February 2026 (Table S2, Section 27). These are real, observed device measurements, not just illustrative or estimated values.
- **Dataset B — independent surface temperature** (Section 8): four thermometer readings of concrete and grass, observed on a separate occasion. These are also real measurements, but they were not collected at the same time as Dataset A.

Because Datasets A and B were not collected simultaneously, they cannot yet be combined into a calibration curve (Section 9) or used to test H5 (Section 4). An earlier planning stage of this project used illustrative, made-up phone values purely to show what a future combined calibration table might eventually look like; those placeholder numbers have now been fully replaced by the real observations in Dataset A, and none remain in this manuscript. The rule going forward is the same one that produced this correction: a number is only reported as a result if it can be traced to an actual notebook entry (Table S1 or Table S2), and anything else is explicitly marked as a hypothesis, an estimate, or future work.

11. Device Thermal-Response Metrics: ΔT and STRI

The primary, physically direct metric used in this pilot is the device’s own temperature change relative to its baseline:

$$\Delta T_d = T_{d,exposed} - T_b$$

where $T_{d,exposed}$ is the phone’s internal temperature after the defined exposure period and T_b is that same device’s own indoor baseline (Section 5.10).

For comparison across devices and conditions, this pilot also reports a normalized *Smartphone Thermal Response Index* (STRI):

$$STRI = [(T_{d,exposed} - T_b) / T_b] \times 100$$

STRI should be read as a device thermal-response index, not as a direct measure of surface heat contribution — a deliberate departure from this project's earlier working name ("Surface Heat Contribution Index"). An STRI of +15%, for example, means only that the phone's internal temperature finished 15% above its own baseline. It does not mean the surface itself got 15% hotter, and it does not mean that 15% of the heat "came from" the surface in any quantitative sense.

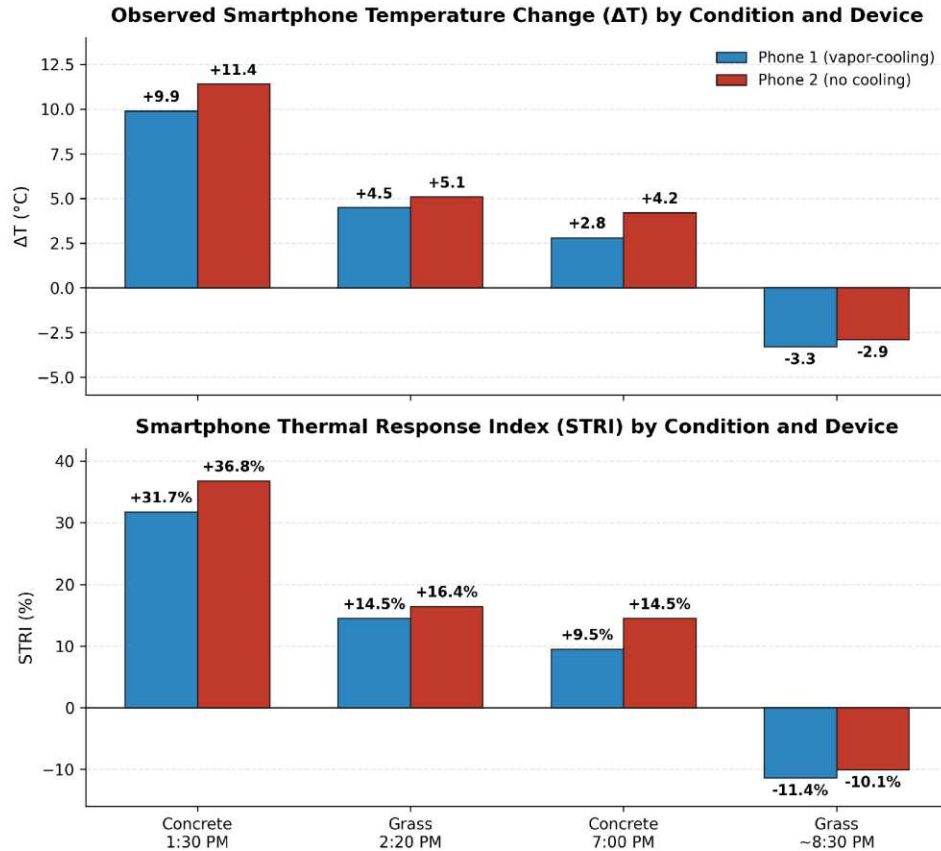
A related naming correction: the original laboratory notebook labelled the post-exposure phone reading " T_s (equilibrium temperature)". In the notation adopted for this manuscript (Section 5.10), T_s is reserved for surface temperature, measured independently. The notebook's " T_s " was always the device's own internal reading, so it is relabelled $T_{d,exposed}$ throughout — the underlying numbers are unchanged, only the symbol is corrected.

12. Pilot Findings

The table below reproduces all eight paired observations from the 25 February 2026 laboratory notebook (Table S2, Section 27) exactly as recorded, with $T_{d,exposed}$ relabelled from the notebook's original " T_s " per the correction noted in Section 11.

Surface (time)	Device	Baseline T (°C)	Exposed T (°C)	ΔT (°C)	STRI
Concrete (1:30 PM)	Phone 1 (vapor-cooling)	31.2	41.1	+9.9	+31.73%
Concrete (1:30 PM)	Phone 2 (no cooling)	31.0	42.4	+11.4	+36.77%
Grass (2:20 PM)	Phone 1 (vapor-cooling)	31.0	35.5	+4.5	+14.51%
Grass (2:20 PM)	Phone 2 (no cooling)	31.0	36.1	+5.1	+16.45%
Concrete (~7:00 PM)	Phone 1 (vapor-cooling)	29.5	32.3	+2.8	+9.49%
Concrete (~7:00 PM)	Phone 2 (no cooling)	29.0	33.2	+4.2	+14.48%
Grass (~8:30 PM)	Phone 1 (vapor-cooling)	28.9	25.6	-3.3	-11.42%
Grass (~8:30 PM)	Phone 2 (no cooling)	28.7	25.8	-2.9	-10.10%

n = 1 trial per condition per device. Source: laboratory notebook, 25 February 2026 (Table S2, Section 27).



Source: laboratory notebook, 25 February 2026 (Section 12, Table). $n = 1$ trial per condition per device; not simultaneous across surfaces (Section 14).

Figure 3. Observed device temperature change (ΔT) and STRI across the four field conditions, by device (Section 12). Bars below zero indicate a device reading below its own baseline.

12.1 Concrete Produced a Higher Daytime Thermal Response

Under the observed daytime conditions, both phones warmed substantially more on concrete (1:30 PM) than on grass (2:20 PM): ΔT of +9.9 $^{\circ}\text{C}$ and +11.4 $^{\circ}\text{C}$ on concrete, versus +4.5 $^{\circ}\text{C}$ and +5.1 $^{\circ}\text{C}$ on grass, for Phone 1 and Phone 2 respectively. Because concrete and grass were measured roughly 50 minutes apart rather than at the same time, this cannot be read as a fully controlled surface-type comparison — ambient conditions may have shifted between the two trials (Section 14). The honest claim is: under the observed daytime conditions, smartphones exposed to concrete exhibited larger temperature increases than those exposed to grass.

12.2 Evening Concrete Stayed Positive; Grass Turned Negative

At the evening concrete trial (~7:00 PM), both phones remained above their own baseline (+2.8 $^{\circ}\text{C}$ and +4.2 $^{\circ}\text{C}$). At the later grass trial (~8:30 PM), both phones read below their own baseline (–3.3 $^{\circ}\text{C}$ and –2.9 $^{\circ}\text{C}$). The observation, stated carefully, is that the devices stayed warmer than baseline on concrete into the evening, while they read cooler than baseline on grass roughly ninety minutes later. This is consistent with thermal persistence on concrete — a more defensible description than calling concrete a "thermal battery" — but the mechanism has not been isolated: it could reflect heat stored and released

by the concrete, a simply colder grass surface at a later and cooler hour, or some combination of both (Section 14).

12.3 The Two Devices Responded Differently

Phone 2 (no cooling feature) showed a larger ΔT than Phone 1 (vapor-cooling feature) in every one of the four matched conditions — for example, +11.4 °C versus +9.9 °C on daytime concrete, and +4.2 °C versus +2.8 °C on evening concrete. This is consistent with H3 and with the contact-resistance / internal-architecture discussion in Section 5.9, but with $n = 1$ device of each type, it remains an exploratory, device-specific observation rather than a demonstrated hardware effect. The stronger, appropriately scoped claim is: differences in thermal architecture were associated with different device temperature responses under the tested conditions — not a general claim about "cheap phones" versus "expensive phones," since price and thermal design were not independently varied here.

12.4 Correcting an Earlier Percentage Comparison

An earlier working version of this analysis reported that concrete's thermal contribution was "216% higher" than grass's. Recomputed directly from the STRI values above, concrete's daytime STRI is approximately 2.2× grass's: 31.73% vs. 14.51% for Phone 1 ($\approx 119\%$ higher, not 216%), and 36.77% vs. 16.45% for Phone 2 ($\approx 123\%$ higher). The error in the original figure came from a normalization slip rather than an actual data error — the raw temperatures above are unaffected. This manuscript reports ΔT and STRI directly, rather than a single derived ratio, both because the raw values in the table above are more directly interpretable and because a ratio of two STRI values compounds the limitations already attached to STRI itself (Section 11).

Taken together, these are observations from a single trial per condition per device, not an exact proof of causation. The dataset is far too small to support general claims about concrete, grass, or device tiers at large — closing that gap is exactly what this design in Section 15 is meant to do.

13. The Hardware Heat Tax Concept

"*Hardware Heat Tax*" is a conceptual construct here, not a quantified physical quantity. It is hypothesized to represent the extra thermal burden a device may incur as a result of its geographic location:

urban surface → device thermal exposure → possible technological consequences.

Of interest to be quantified in this pilot, but not yet measured, is whether that extra exposure leads to greater thermal throttling, altered charging behavior, accelerated battery aging or a demonstrable impact on usability. None of which can be inferred merely from a rise in temperature, each requiring its own measurement (see Section 26.1 for supporting literature on thermal throttling and heat-driven battery degradation).

Nested within this hypothesis is the possibility of a technologically-mediated digital inequity: if cheaper devices genuinely exhibit higher temperatures under the same conditions, and if cheaper devices are disproportionately exposed to high-heat environments, a technological resilience gap could be forming. This is a real possibility worth taking seriously, but would require much larger samples, socioeconomic data, and direct measurements of device health, not simply a temperature reading.

14. Major Limitations

The table below restates each limitation of the current pilot alongside the specific Version 2 phase (Section 15) designed to address it — making the study's gaps explicit rather than leaving them implicit.

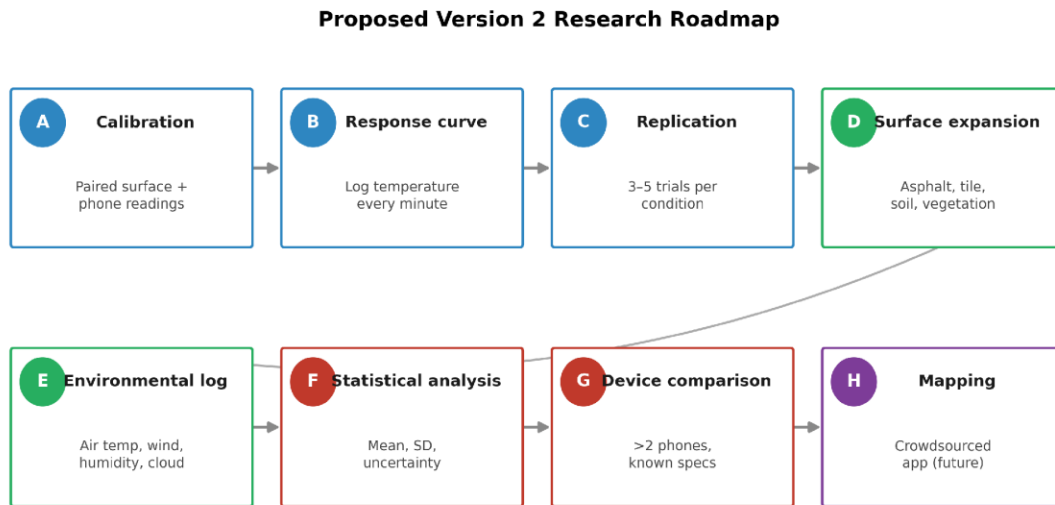
Limitation	Why It Matters	How This Research Addresses It
Internal phone temperature is not direct surface temperature.	The device reading could be misread as a surface measurement.	Phase A pairs surface-thermometer and phone readings to quantify the offset.
Thermal lag between the surface and internal sensor has not yet been quantified.	Instantaneous surface and device readings may not correspond in time.	Phase B logs temperature every minute to reveal lag and heating dynamics.
Phone temperature can be affected by internal electrical activity.	Confounds the surface signal with the device's own workload.	Airplane mode / closed-app protocol (7.2) plus Phase A calibration controls for this.
Direct sunlight adds radiative heating, confounding a conduction-focused experiment.	Mixes two physically distinct heat pathways into one reading.	Phase E logs solar exposure so radiation and conduction can be separated.

Limitation	Why It Matters	How This Research Addresses It
Convection and wind can change heat loss from the phone.	Adds an uncontrolled environmental variable.	Phase E logs wind and air temperature alongside each trial.
Contact pressure, contact area, and phone orientation may affect heat transfer.	Changes the conduction pathway between trials.	Fixed placement protocol specified for Phase C replication trials.
Small sample size and limited replication.	Cannot establish whether the observed pattern is reproducible.	Phase C runs 3–5 independent trials per condition.
Only a small number of materials and locations were studied.	Findings cannot generalize beyond concrete and grass.	Phase D adds asphalt, tile, bare soil, and additional vegetation types.
STRI is a newly proposed index and requires validation before broader use.	The normalized index has not been benchmarked against an external reference.	Phases A and F pair the index against thermometer readings and report uncertainty statistically.
Claims about battery degradation or digital inequality are currently hypotheses, not demonstrated outcomes.	These extend beyond what a temperature reading alone can establish.	Phases G and H (device comparison, mapping) are reserved for future work, not claimed here.
Concrete and grass trials were not run simultaneously (~50 minutes apart during the day; separate sessions in the evening).	Ambient conditions may have drifted between trials, confounding a clean surface-to-surface comparison.	Phase C is designed to run time-matched or simultaneous trials across surfaces; Phase E logs conditions at each trial.
The 1:09 PM baseline was reused for both the 1:30 PM concrete and 2:20 PM grass trials rather than re-measured immediately before each (Section 7.2).	It is not confirmed that either phone had returned to that baseline by 2:20 PM.	Protocol revision: re-equilibrate and re-record baseline immediately before every individual exposure.
Only one device of each thermal-architecture type was tested ($n = 1$ per type).	Cannot distinguish an individual-unit effect from a true architecture effect.	Phase G tests more than two phones per architecture type where possible.
No direct heat-flux measurement was made.	Temperature alone cannot quantify the rate or amount of heat actually transferred.	Noted as a longer-term instrumentation upgrade

Limitation	Why It Matters	How This Research Addresses It
		beyond the current Version 2 scope.

15. Improved Experimental Design

The next stage of this project needs to focus on validation, not simply on collecting more numbers. Figure 4 lays out the proposed sequence.



Sequence reflects the study's proposed validation-first priority (Section 15); phases may run partly in parallel.

Figure 4. Proposed Version 2 research roadmap (Section 15).

- **Phase A — Calibration.** Collect paired surface-temperature and phone-temperature measurements, at several temperatures and under both shade and controlled illumination.
- **Phase B — Response curve.** Record phone temperature every minute instead of only at the 10-minute mark, to reveal heating rate and thermal lag.
- **Phase C — Replication.** Run at least 3–5 independent trials for each surface × condition × device combination, where practical.
- **Phase D — Surface expansion.** Add asphalt, tile, bare soil, painted surfaces, and additional vegetation types.
- **Phase E — Environmental recording.** Log air temperature, humidity, wind, cloud cover, solar exposure, surface moisture, and exact time.

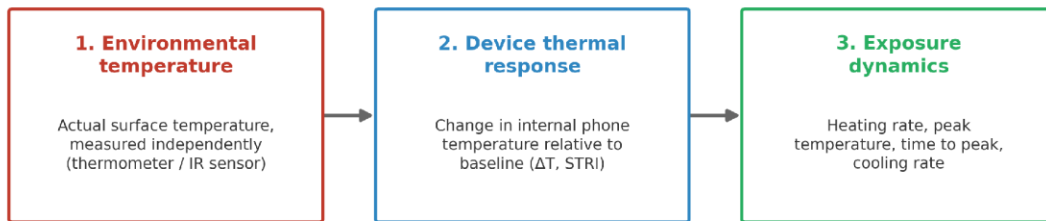
- **Phase F — *Statistical analysis*.** Report mean, standard deviation, and uncertainty; compare groups with an appropriate test only once repeated data exist.
- **Phase G — *Device comparison*.** Test more than two phones where possible, recording model, age, battery condition, and thermal-management features.
- **Phase H — *Mapping*.** Only after the measurement method is validated should a future app be considered for crowdsourced mapping.

16. A Better Measurement Framework

A more mature version of this project needs to keep three quantities separate, rather than folding them into a single number (Figure 5):

- Environmental temperature (the actual surface temperature, measured independently)
- Device thermal response (the change in internal phone temperature relative to baseline)
- Exposure dynamics (heating rate, peak temperature, time to peak, and cooling rate)

A Better Measurement Framework: Three Quantities Kept Separate



Kept as three separate, explicitly-linked quantities — not collapsed into one number — so that surface heat, device response, and response timing can each be checked on its own.

Figure 5. The three quantities this project needs to track separately (Section 16).

This separation matters because two surfaces at the same temperature can still produce different device responses depending on contact properties, while two phones on the same surface can respond differently because of their own thermal architecture.

17. Potential Data Analysis

The following variables can be calculated from each trial. ΔT and STRI have already been calculated for all eight pilot observations (Section 12); heating rate, cooling rate, and calibration residual remain pending until continuous logging and paired surface measurements are available (Section 27, Tables S3–S4).

- $\Delta T = T_{\text{exposed}} - T_{\text{baseline}}$

- *Heating rate* = $\Delta T / \text{exposure time}$
- *STRI* = normalized temperature change
- *Calibration residual* = observed surface temperature – calibrated estimate
- *Cooling rate* = temperature decrease per minute after removal from the surface

A useful graph set would include:

- Surface temperature vs. phone temperature
- Phone temperature vs. time
- STRI by surface
- STRI by device
- Heating and cooling curves
- Calibration residuals

Error bars should be added once repeated measurements are available.

18. Why the Project Could Be Useful

If validated, this approach could complement, rather than replace, conventional thermal measurements. Potential uses include:

- Low-cost, micro-scale thermal observations.
- Comparison of surface materials.
- Citizen-science thermal observations.
- Investigation of device exposure in hot urban environments.
- Educational measurement of heat-transfer concepts.
- **Hyper-local heat mapping:** a validated version of this method could, in principle, reach a street-level spatial resolution that fixed weather stations and satellite land-surface-temperature products do not cover, since every participating phone becomes a measurement point rather than a remote pixel.
- **Comparative material ranking:** once calibrated, repeated STRI measurements across paving or coating materials could help rank which surfaces impose the least device (and, by extension, pedestrian) thermal load — a possible input to material choices in future urban design.
- **Device heat-safety awareness:** identifying environments that reliably produce a large device thermal response could inform simple, practical guidance on where sustained heat exposure is more likely to affect personal electronics — connecting back to the Hardware Heat Tax and digital-equity questions raised in Section 13.

Each of these is a motivation for pursuing this version, not a claim about what the current eight-observation pilot has already shown. The strongest scientific claim here is not that a smartphone can replace a thermometer or other thermal sensor. It is that a smartphone may offer a low-cost measurement of device-experienced thermal response, and that this response can potentially be related to environmental surface conditions once properly calibrated.

19. Future Research Questions

- How stable is the relationship between surface temperature and internal phone temperature?
- How long does a phone take to respond to a change in surface temperature?
- Does contact area or pressure significantly alter the response?
- How much of the daytime response comes from solar radiation rather than conduction?
- Do different phone designs show reproducible differences in thermal response?
- Can a calibrated phone response identify relative thermal hotspots?
- How does surface moisture change the thermal response of grass and soil?
- Can the method provide useful information at street scale when combined with location and environmental metadata?

20. Conclusion

This study introduces *Active Thermal Mapping* as a proof-of-concept for examining the thermal environment through the lens of an electronic device. Grounded in eight paired baseline/exposed measurements recorded on 25 February 2026 (Section 12), the pilot shows that concrete produced a greater device thermal response than natural grass during the daytime trials, and that this response persisted above baseline into the evening on concrete while the grass reading fell below baseline. It also shows that the two phones tested did not respond identically within the same environment.

The central scientific challenge ahead is validation. A phone's internal temperature is not the same quantity as surface temperature, and the measured result is the interaction of conduction, convection, radiation, and internal heat generation. Instead of treating those variations as failures, the next step is to directly measure and model them.

The project then moves from a single experiment toward a testable research framework: measure the surface, measure the device, quantify the relationship, estimate the uncertainty, and only then determine whether the device can be used for localized thermal exposure assessment. At this stage, the Hardware Heat Tax should be treated as a proposed concept and hypothesis, not an established effect. With calibration, replication, and appropriate precautions, the project could become a solid study linking urban climatology, heat transfer, and technological resilience.

21. Data Availability Statement

Two primary datasets underlie this manuscript, both transcribed directly from the author's laboratory notebook and reproduced in full in the Supplementary Material (Section 27): the four independent surface-thermometer measurements of Section 8 (Table S1), and the eight paired smartphone baseline/exposed-temperature observations of Section 12, recorded on 25 February 2026 (Table S2). These two datasets have not yet been paired at matching times and locations, so no combined calibration dataset yet exists (Section 9). Environmental-conditions logging (Table S3) and continuous, minute-by-minute device temperature logging for heating-rate and cooling-rate analysis (Table S4) are not yet available and are planned as part of this protocol (Section 15).

22. Ethics and Safety Statement

This study involved no human participants, animals, biological samples, or personally identifiable data. All measurements were of inanimate surfaces (concrete and grass/ground) and consumer electronic devices in publicly accessible outdoor locations.

23. Conflict of Interest Statement

The author declares no competing financial or non-financial interests related to this work.

24. Author Contributions

Shubhadeep Podder conceived the study, designed the experimental protocol, collected and analysed the available data, produced the figures, and prepared the manuscript.

25. Suggested Research Vocabulary

Term	Meaning
Urban Heat Island (UHI)	Urban areas can experience different thermal conditions from surrounding, less-developed areas.
Land Surface Temperature (LST)	Temperature of the land surface, inferred or measured using appropriate instruments.
Conduction	Heat transfer through direct physical contact.
Convection	Heat transfer involving a moving fluid, including air.
Radiation	Energy transfer through electromagnetic radiation, including sunlight and thermal infrared.
Thermal inertia	The tendency of a material or system to resist rapid temperature change because of its thermal properties.
Thermal conductivity	A material property describing its ability to conduct heat.
Heat capacity	The amount of energy needed to change a material's temperature by a given amount.
Thermal lag	The delay between a change in an external thermal condition and the measured response.
Contact resistance	The resistance to heat flow arising at an interface between two materials in contact (Section 5.9).
ΔT (device temperature change)	The physically direct difference between a device's exposed and baseline internal temperatures (Section 11).
Smartphone Thermal Response Index (STRI)	A normalized index describing how far a device's internal temperature has moved from its own baseline; not a direct measure of surface heat contribution (Section 11).
Calibration	Establishing a quantitative relationship between a measurement system and a reference measurement.
Validation	Testing whether a method performs adequately against an independent reference or expected behaviour.
Proxy	A measurable quantity used to represent another quantity that is harder to measure directly.

26. Related Work and References

26.1 Related Work

The literature below moves roughly from smartphone-based environmental sensing, to satellite and land-surface-temperature retrieval, to vegetation thermal behaviour, to citizen-science UHI measurement, and finally to the technological-consequences literature underlying the Hardware Heat Tax hypothesis (Section 13). Read in that order, it illustrates this pilot's specific gap: existing work measures ambient air temperature or remotely sensed land-surface temperature, but not the contact-scale thermal load experienced by a device resting directly on a surface.

The concept of deriving environmental signals from the sensors built into a smartphone is not new: Overeem et al. (2013) demonstrated that battery temperatures measured passively by an Android application, along with only a simple heat-transfer model, recovered reasonably accurate daily air temperatures for several major cities — arguably the closest precedent for this project's primary innovation, albeit with a target of ambient air temperature rather than direct contact with a surface.

Gavin and Sidhu (2015) directly compared the smartphone's built-in temperature sensor to a reference-standard instrument and saw no statistically significant difference for ambient readings, which is a welcome validation for any effort building on the phone's sensors, albeit again without surface contact; de Araújo, Silva, and Moreira (2017) examine the same basic question from an angle of data quality and find that the smartphone's temperature reports are reliable primarily when the device is left undisturbed — active handling introduces exactly the kind of internal heat signatures this pilot has sought to isolate. Between these studies, the general consensus holds that a smartphone's internal sensor contains a genuine signal, and that isolating that signal from the behaviour of the device itself is the critical challenge — exactly the task undertaken in careful detail by Sections 9 and 10 of this paper.

In the environmental domain, the work on land-surface temperature by Tomlinson, Chapman, Thornes, and Baker (2011) and the survey by Zhou et al. (2019) describe how satellites such as the UK's Meteosat infer the temperature of the surface beneath them via thermal-infrared radiation at the city scale — a very different instrument and spatial extent from a single phone on a single patch of concrete, but aimed at the same physical target, land-surface temperature, that the present project approaches from the ground up rather than from overhead.

The vegetation side of the story appears to be even more mixed and nuanced than previously thought: Yu et al. (2024) find that shading and evapotranspiration together contribute to a measurable cooling benefit for urban vegetation that persists into the evening, which corroborates the negative evening STRI readings reported here for grass; but a 2026 global study led by Zhou et al., spanning 761 cities, found that grass and cropland in regions of arid, water-scarce climate can actually run warmer than their built surroundings due to insufficient evaporative capacity — a reminder that this project's general finding (that grass is cooler than concrete) should probably be read as a seasonal, climate-dependent phenomenon rather than an invariant truth.

The low-cost distributed measurement approach used by this project also has precedents as a measurement strategy, not just as an idea: NOAA's National Integrated Heat Health Information System and CAPA Strategies have since 2017 engaged citizens in a number of U.S. cities in measuring Urban Heat Islands through the creation of heat maps, in which volunteers drive fixed routes with car-mounted sensors that feed high-resolution heat maps. The Hardware Heat Tax framework proposed in Section 13 targets something related but not identical — not ambient heat, but the thermal load experienced by the phone itself — and may eventually be able to leverage a similar volunteer-driven, route-based measurement programme once the measurement method has been validated.

Finally, for the "possible technological consequences" point in Section 13: both Sahin and Coskun, and independently Bantock, Al-Hashimi, and Merrett, have documented that sustained heat measurably degrades smartphone performance through thermal throttling — not only the battery's chemistry but an actual user-visible slowdown in performance. This bolsters the Hardware Heat Tax concept as a genuine possibility with a plausible mechanism worth targeting directly, rather than merely a temperature measurement.

26.2 References

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27. Supplementary Material (Appendix)

The tables below separate what has actually been measured from what Version 2 (Section 15) is designed to collect, consistent with the Observed vs. Estimated principle in Section 10.

Table S1 — Raw Surface Thermometer Measurements (observed data)

Surface	Condition	Thermometer Surface Temperature
Concrete	Shade	37.72 °C
Concrete	Direct sunlight	46.11 °C
Ground / grass	Shade	36.27 °C
Ground / grass	Direct sunlight	41.83 °C

n = 1 reading per condition; measurement window $\approx$ 12:00 PM $\pm$ 15 minutes (Section 8).

Table S2 — Raw Smartphone Temperature Measurements (observed data)

Transcribed directly from the laboratory notebook of 25 February 2026. ΔT and STRI are included here as they were calculated alongside the raw readings in the original notebook; see Section 12 for the same table with full discussion, and Section 11 for the corrected T_d , exposed notation.

Surface (time)	Device	Baseline T (°C)	Exposed T (°C)	ΔT (°C)	STRI
Concrete (1:30 PM)	Phone 1 (vapor-cooling)	31.2	41.1	+9.9	+31.73%
Concrete (1:30 PM)	Phone 2 (no cooling)	31.0	42.4	+11.4	+36.77%
Grass (2:20 PM)	Phone 1 (vapor-cooling)	31.0	35.5	+4.5	+14.51%
Grass (2:20 PM)	Phone 2 (no cooling)	31.0	36.1	+5.1	+16.45%
Concrete (~7:00 PM)	Phone 1 (vapor-cooling)	29.5	32.3	+2.8	+9.49%
Concrete (~7:00 PM)	Phone 2 (no cooling)	29.0	33.2	+4.2	+14.48%
Grass (~8:30 PM)	Phone 1 (vapor-cooling)	28.9	25.6	-3.3	-11.42%
Grass (~8:30 PM)	Phone 2 (no cooling)	28.7	25.8	-2.9	-10.10%

n = 1 trial per condition per device. The 1:30 PM and 2:20 PM baselines were shared rather than independently re-measured (Section 7.2, Section 14).

Table S3 — Environmental Conditions Log

Pending. Clock times are recorded in Table S2, but air temperature, humidity, wind, cloud cover, surface moisture, and shade/sun status were not independently logged for these eight trials. To be recorded under Section 15, Phase E.

Table S4 — Exposure Dynamics (heating rate, cooling rate, time-to-peak)

Pending. Each trial in Table S2 used a single before/after reading rather than continuous logging, so a heating or cooling curve cannot be reconstructed from the current data. Minute-by-minute logging is planned under Section 15, Phase B.