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Constructing high-frequency, spatially granular cement production activity indices from satellite imagery

Hannes Coetsee*

Abstract

The construction sector is an important barometer of broader economic momentum in South Africa, yet indicators of activity are typically published with a lag, are available at low frequency and offer limited spatial disaggregation. These features reduce their usefulness for the timely identification of turning points and for real-time monitoring. This paper develops high-frequency, near-real-time and spatially granular indices of cement production activity from publicly available Sentinel-2 satellite imagery. The indices are compiled at five-daily and monthly frequencies and at the national, provincial and plant levels. To our knowledge, this is the first indicator derived from satellite imagery to be developed for South Africa and the only current publicly documented measure of cement production activity for the country. The indices track developments in the construction sector, provide a timely complement to conventional indicators and offer useful signals for near-term monitoring and spatial analysis.

JEL classification

C55, E01, E32, R15

Keywords

Remote sensing, construction, high-frequency indicators, nowcasting

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1. Introduction[1]

Timely, spatially granular measures of construction activity in South Africa are limited, even though policy analysis and nowcasting often require them. The construction sector is a useful bellwether of economic momentum, which makes the timely identification of turning points in the sector particularly important. Existing indicators, including materials prices, building plans passed and completed, and business confidence, are informative about broader trends, but they are not designed primarily for real-time monitoring. Publication lags and their relatively low frequency limit their usefulness for short-horizon assessment, while most series are available only at the national level, which constrains the analysis of regional variation.[2]

To address this gap, we develop a higher-frequency, concurrent indicator of construction activity using satellite imagery. Satellite data are objective, geographically referenced and consistently observed over time, making them well suited to the construction of subnational indicators.

A growing literature shows that alternative, observation-based data can complement official statistics by providing earlier and more granular measures of real economic activity, particularly where conventional data are lagged or incomplete. Satellite-derived indicators such as night-time lights, thermal anomalies and port imagery, together with automatic identification system shipping data, have been used to monitor economic momentum, trade flows and congestion in near real time (Cerdeiro et al. 2020a, 2020b; Arslanalp et al. 2025; Spelta, Pagnottoni and Pecora 2025). For construction activity, d'Aspremont et al. (2023) derive daily plant-level measures from the infrared signatures of cement kilns and show that these measures co-move with cement output and broader construction indicators across countries.

This paper builds on the approach by d'Aspremont et al. (2023). Relative to that framework, we adapt the frequency to the Sentinel-2 revisit schedule (approximately

[1] I am grateful to Lesego Chanza and Luchelle Soobyah and the SARB Model Development Division for comments and suggestions.

[2] Materials prices and building plans passed and completed are monthly and released by Statistics South Africa, while the Bureau for Economic Research (BER), in collaboration with First National Bank (FNB), releases the Building Confidence Index quarterly.

3.8 days, yielding a five-daily index), expand plant coverage in South Africa to 21 facilities, refine plant-status classification using heat density and nameplate capacity, and compile province-level indices in both five-daily (i.e. every five days) and monthly form.

The focus on cement is motivated by several considerations. Cement is a practical barometer of construction momentum: it is materials- and energy-intensive, responds to changes in financing conditions and public investment, and is only imperfectly captured in timely official statistics. In South Africa, developments in the sector are also shaped by electricity availability and, more recently, by import competition, which further strengthens the case for a timely and spatially granular indicator. Most importantly, there is no single publicly available, spatially disaggregated measure of cement production volumes or activity for South Africa.[3]

This paper's contribution is therefore both empirical and practical. The index developed in this paper tracks short- and longer-term developments in South Africa's construction sector, reflecting the broad decline observed over the past decade and co-movements with established indicators. The index is positively associated with measures such as domestic cement sales, construction activity at basic prices, electricity production, and building plans passed and completed; and negatively associated with supply-chain pressures, materials cost indices and cement imports.[4] Although the signal generally moves at the same time as, or slightly after, standard indicators, it is available much earlier than official data releases. This gives it practical value as an early indicator of economic developments.

The provincial breakdown offers a useful tool for monitoring subnational developments, while the five-daily frequency enables analysts to assess events such as severe power disruptions or large infrastructure rollouts without waiting for monthly publications.[5]

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3 The closest approximation is Statistics South Africa's monthly domestic cement sales, which are also released with a lag.

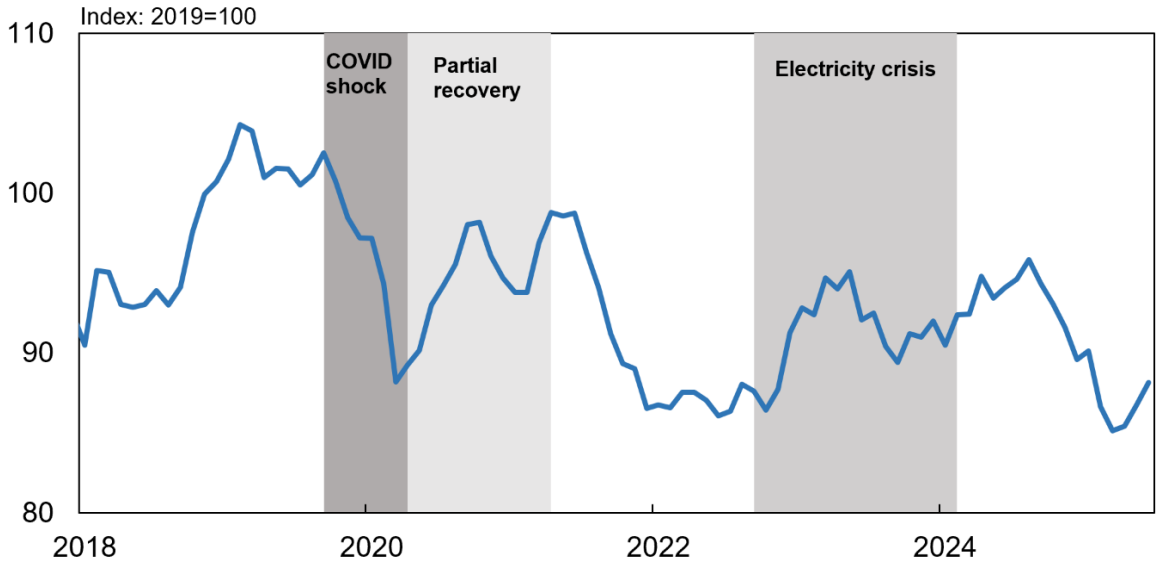
4 Correlation and comparative analysis are conducted in section 5.

5 While the provincial estimates are an important contribution of the paper, they should be interpreted with caution. Their accuracy may vary across plants and regions because cloud coverage is not uniform. In particular, KwaZulu-Natal experiences relatively high cloud coverage, which may obscure satellite observations and increase reliance on interpolated values. The

While this paper does not undertake formal forecasting exercises, d'Aspremont et al. (2023) show that similar satellite-based indicators improve forecasting performance relative to standard approaches when predicting cement production in countries where such data are available, and that they are also useful for nowcasting broader construction activity. For South Africa, the authors report improvements using this indicator, above the global average, when nowcasting non-metallic mineral products, reflecting the absence of a direct cement production series.[6]

Figure 1 illustrates the constructed national cement production activity index over time. For ease of interpretation, the figure presents the monthly index together with a six-month moving average to highlight longer-term developments. Activity declined ahead of the COVID-19 pandemic and weakened further during that episode, recovering only partially thereafter. From 2021 to late 2022, activity weakened again, with some resilience during periods of severe load-shedding. This is notable given the energy intensity of cement production and may reflect operational adjustments by producers in response to electricity constraints. The drivers of these movements and the subnational patterns are discussed in later sections.

Figure 1: The SARB satellite-derived cement production activity index*



Source: SARB.

Note: *Six-period moving average applied.

disaggregated estimates for such regions may therefore be less precise than those for areas with more consistently clear imagery.

6 The data are sourced from the Organisation for Economic Co-operation and Development.

2. Background

South Africa's established set of indicators provides the context within which such signals can be interpreted. Statistics South Africa (Stats SA) publishes monthly building statistics on the value and volume of building plans passed and buildings completed, which are commonly used as leading and coincident gauges of construction momentum and feed into composite business-cycle indicators (Stats SA 2024–2026; Moody's Analytics 2026). Survey-based measures compiled by the Bureau for Economic Research (BER), including building and civil confidence and the Building Cost Index, provide timely qualitative and tender-price information on activity, input pressures and margins, and have a long record of correspondence with official series (BER 2025, 2026). Sectoral reports, such as the Government Technical Advisory Centre's (GTAC's) infrastructure trends report and Rider Levett Bucknall's cost intelligence report, document prolonged weakness in construction gross value added (GVA) as well as episodes in which input inflation exceeded tender price escalation, implying margin compression and state-dependent pass-through (GTAC 2025; Rider Levett Bucknall 2025).

Two structural features are particularly relevant for interpreting construction-related indicators in South Africa. First, electricity availability significantly affects industrial and construction activity. South African Reserve Bank (SARB) research and firm-level evidence point to negative effects of load-shedding on output and profitability, implying that energy constraints can drive short-run fluctuations and complicate simple inferences from input prices to output (Janse van Rensburg and Morema 2023; Zulu and Maama 2024). Second, import competition has reshaped coastal cement markets. Industry monitoring indicates a rise in cement imports since 2023, often from Vietnam and routed through Durban, Gqeberha and Cape Town, despite logistical bottlenecks (Chronux Research 2024; Industry Insight 2024, 2025). Policy responses, including anti-dumping duties on Pakistani cement administered by the International Trade Administration Commission (ITAC) and the South African Revenue Service (SARS), together with firm-level capacity adjustments, have also affected local pricing and utilisation (ITAC 2015; SARS 2025; Perilli 2025).

This context is important for understanding both what is measured in this paper and how the resulting indicator is evaluated. On the pricing side, Stats SA's Construction

Material Price Indices capture input-cost movements, while the BER's Building Cost Index reflects tender prices that incorporate margins and market conditions. Evidence from South Africa and elsewhere suggests that pass-through from input costs to output prices is incomplete, state-dependent and slower in downturns. Exchange-rate pass-through to consumer prices has also declined under credible inflation targeting and is lower when inflation remains within the inflation target band (Kabundi and Mbelu 2016; Ndou 2022; Kharroubi et al. 2023). These findings support the use of a broad set of contemporaneous comparators, rather than reliance on a single benchmark, when interpreting a high-frequency activity signal.

Against this background, the paper tailors a kiln-activity indicator to South Africa's spatial and institutional context and evaluates its behaviour alongside comparative indicators. The objective is not to replace official statistics or to build a complex modelling framework around the index, but to demonstrate the practical value of a transparent signal that is updated at five-daily and monthly frequencies and can be aggregated to provinces where official series are lagged or too aggregated for subnational analysis. Cement production activity can therefore serve as a useful proxy for regional construction activity, particularly in the absence of high-frequency, real-time indicators for the sector. For further detail on the physical cement production process and the structure of the South African cement industry, see Annexure A.

3. Data

The index tracks the heat footprints of 21 cement production plants in South Africa, with production capacity ranging from 0.2 to 2 million tonnes per year (Mt/yr).[7] Plant locations and production capacities were obtained from publicly available industry sources.[8]

The index is constructed from images captured by the European Space Agency's Sentinel-2A and Sentinel-2B satellites, launched in 2015 and 2017 respectively. Each

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7 PPC Gqeberha (Eastern Cape) and Afrimat Lichtenburg (North West) respectively.

8 Most plant locations are sourced from https://www.cemnet.com/global-cement-report/country/south-africa, while production capacity is sourced from a variety of company websites, as well as from https://www.globalcement.com/magazine/articles/894-the-cement-industries-of-southern-africa

image is downloaded in GeoTIFF format and contains several spectral bands, each corresponding to a specific wavelength range detected by the satellite sensors.[9] Although 11 bands are available, heat detection uses a subset of three bands: the near-infrared (NIR) band and the shortwave-infrared (SWIR) bands 11 and 12. These bands provide information that can be used to infer high-temperature activity at ground level.

For most of the relevant bands, the spatial resolution is 20 square metres per pixel, and each image comprises 512 by 512 pixels. The mean revisit time is about 3.8 days. To maintain a consistent and manageable frequency, images are downloaded and processed at five-day intervals.[10] Images are available from July 2017, and the sample used in this paper runs from 5 July 2017 to 1 July 2025, yielding about 594 observations per plant and 12 474 plant-level observations in total.

Cloud coverage is a well-known challenge in remote-sensing applications because clouds can obscure the earth's surface. In addition, weather patterns may themselves be correlated with production and demand conditions in the cement sector, which makes careful treatment of cloud coverage important for interpretation. Cloud masks are generated using Sentinel Hub's s2cloudless LightGBM classifier and cross-checked against the decision-tree approach of Hollstein et al. (2016) for Sentinel-2 imagery.[11,12] This approach assigns each pixel a probability of cloud cover based on the spectral response of the image. We test sensitivity to alternative threshold values and report the implications for series completeness, adopting a conservative 20% cloudy-pixel cutoff. After masking, images with cloud coverage above this threshold are treated as missing.[13] Missing values are then interpolated, as discussed in section 4.3.

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9 There are three visible light spectrum bands (red, green and blue), several red-edge bands, as well as NIR, SWIR and atmospheric bands used for correction.

10 This reduces the likelihood of processing consecutive images that contain duplicate information.

11 The Hollstein dataset includes scenes from South Africa.

12 For more on this method, refer to the blog post by the creators at https://medium.com/sentinel-hub/improving-cloud-detection-with-machine-learning-c09dc5d7cf13, and the GitHub page at GitHub – sentinel-hub/sentinel2-cloud-detector: Sentinel Hub Cloud Detector for Sentinel-2 images in Python.

13 There is a trade-off regarding threshold values: a low threshold implies higher-quality images, but fewer observations over time. As we are limited in the number of images available (in contrast to

The cement production process requires very high temperatures, often more than 1000°C, to facilitate the chemical reactions that produce clinker. This is achieved in large, specialised kilns.[14] These kilns generate heat footprints that can be detected by modern NIR and SWIR sensors. Following d'Aspremont et al. (2023), two algorithms are used to detect these heat footprints. Because Sentinel-2 does not include thermal bands, very hot surfaces are identified indirectly using SWIR/NIR reflectance-based indices.

The two algorithms, HOTMAP's spectral-contrast rules and an Autonomous Sciencecraft Experiment (ASE) style gradient filter, have been shown to perform well in identifying high-temperature hotspots using moderate-resolution sensors such as MODIS (Murphy et al. 2016). Both rely on the implications of Planck's law for the distribution of wavelengths emitted and reflected by objects at different temperatures.

Figure 2 illustrates the application of the HOTMAP and ASE heat-detection algorithms. HOTMAP, developed by Murphy et al. (2016) and extended by Massimetti et al. (2020), classifies pixels according to three conditions that identify pixels as 'hot', 'very hot' and 'extremely hot' respectively.[15] The ASE algorithm addresses issues of false positives by cross-checking pixels identified as 'hot' by HOTMAP against a country-specific gradient threshold. Further details are provided in Annexure E. In essence, the method exploits contrasts across infrared bands to classify heat intensity. Because longer wavelengths are more sensitive to heat, the contrast between infrared bands increases at higher temperatures.

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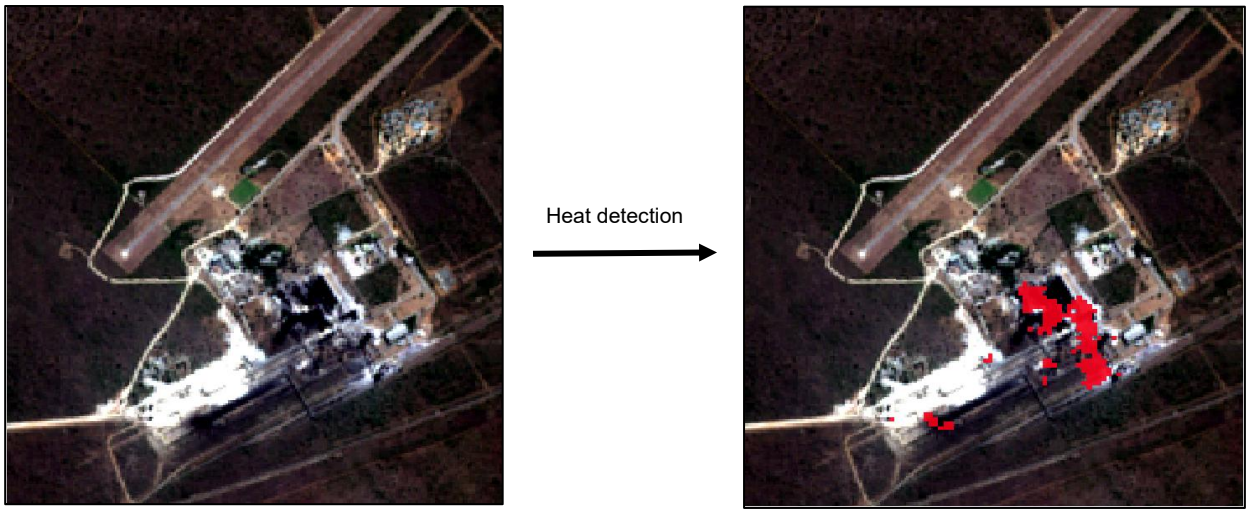
the global coverage of d'Aspremont et al. (2023), a higher threshold was deemed more appropriate. Nonetheless, multiple thresholds were tested, including the threshold of 0.07 used by d'Aspremont et al. (2023). Fortunately, South Africa has low (less than half the global average) cloud coverage, further supporting our decision to use a higher threshold.

[14] The cement rotary kiln is a large, rotating steel tube that slopes at an angle. It rotates on an axis between 30 and 250 revolutions per hour, thereby allowing the raw mix of ingredients to feed into the tube and move slowly down towards the burn pipe to produce clinker (Sephaku Cement 2022).

[15] The thresholds for these conditions were calibrated by Massimetti et al. (2020) on volcanic activity.

Figure 2: Applying the heat-detection algorithm



Source: SARB; Copernicus Sentinel data (2024), processed by Sentinel Hub. Site number 2: Adriaanshoop.

Across the full sample and all plants, daily data gaps may occur primarily because of cloud coverage.[16] These observations are interpolated to obtain complete plant-level time series of heat values. Interpolation is implemented using XGBoost with the following features: (i) lagged observations, (ii) seasonal factors, and (iii) activity at nearby plants within 200 kilometres.[17,18]

Appropriate rolling averages and lags are included among the regressors. The model is estimated separately for each plant using fivefold time-series cross-validation and is evaluated using mean squared error and root mean squared error (RMSE). Hyperparameters are tuned by grid search. The resulting models are then used to

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16 There is variation across plants, with coastal plants in KwaZulu-Natal being the most prone to cloud coverage. Although some observations are missing, the data gaps are primarily attributable to cloud cover rather than underlying plant activity. The interpolation procedure leverages information from historical observations, seasonal patterns and nearby plants, allowing missing values to be inferred from observable activity rather than extrapolated in isolation. As a result, the interpolation process is expected to preserve broad temporal movements in activity while minimising the influence of short-term data gaps.

17 XGBoost – 'eXtreme Gradient Boosting' – is a well-known machine learning method and was found to be most accurate when interpolating for d'Aspremont et al (2023). We use the XGBoost library in Python.

18 These include seasonal factors such as trend and seasonal decompositions, as well as month and week dummies to account for plant maintenance cycles.

interpolate missing values for each plant.[19] The completed plant-level series makes it possible to compute heat densities by plant, which are subsequently used to classify production status as ‘producing’, ‘not producing’ or ‘heating up/cooling down’.

4. Method and indexation

As an indicator, cement production can be linked to domestic construction activity under a number of conditions: inventories of clinker and cement should remain relatively limited; imports and exports should not dominate local demand; there should be no close substitute product; production should continue to track the business cycle despite changes in efficiency associated with maintenance or upgrades; and supply-chain disruptions should not fully decouple production from demand.[20]

Several indices are constructed at different levels of aggregation (plant, provincial and national) and at two frequencies (five-daily and monthly). For the national index, two alternative approaches are considered: the on-off index and a supplementary heat-based indicator. The former is preferred because it classifies production using plant-specific heat distributions and therefore offers greater control for background noise, while the heat-based index follows the original methodology more closely by using heat footprints directly. All indices are weighted by plant production capacity and are rebased to 2019 unless otherwise stated.

As noted above, the methodology differs from that of d’Aspremont et al. (2023) in several respects. First, the indices are compiled at a five-daily frequency rather than a daily frequency. This reflects both the limited observation density available from the

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19 Interpolation is applied to the entire dataset every time new observations are added, thereby adding observations to the training set at each update.

20 Using cement production as a proxy for construction activity relies on several conditions. Domestic production may differ from domestic use because of trade and inventory adjustments, while cement transported across provincial boundaries may be produced and used in different locations. However, imports and exports account for broadly similar shares, which have remained relatively stable over time. Changes in domestic cement production therefore appear to reflect shifts in local demand and production conditions more than fluctuations in cross-border trade. Because the remaining conditions/assumptions are not formally tested, we interpret the indicator as a high-frequency signal containing information about construction activity, rather than a direct measure of construction expenditure or cement consumption.

imagery and the trade-off between temporal granularity and noise introduced by resampling. The chosen frequency therefore remains close to the underlying image release schedule of approximately 3.8 days. Second, the South African index covers more plants (21 rather than 11), making it more representative of local production activity. Third, the plant-status classification procedure is refined by combining plant-level heat-density information with production capacity. Finally, the paper introduces subnational indices at both five-daily and monthly frequencies, disaggregated by South African province.

4.1 The on-off index

This index is compiled by assigning a production status to each plant at each observation date, based on three states: *non-producing/off* (weight 0), *producing/on* (weight 1) and *heating up/cooling down* (weight 0.5).[21] These states correspond to plant-specific ranges of heat density.[22] Modes and troughs are identified algorithmically for each plant, and status is then classified over the intervals between troughs in the density distribution. National and provincial aggregates are obtained as weighted proportions of plants in each status, where the weights are based on plant production capacity.

4.2 The heat-based index

The heat-based index is constructed directly from plant heat footprints and therefore assumes that higher temperatures are associated with higher production activity. Although this relationship is plausible in general, and larger-capacity plants also tend to display larger heat footprints (see Table E1 and Figure E1 in Annexure E), it cannot be fully verified using the plant-level data available here. The heat-based approach is nevertheless retained because it yields smoother plant-level series and may be useful in predictive applications. It also follows the original methodology more closely and is comparatively straightforward to implement. Relative to the classified index, however,

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[21] This corresponds with what the densities look like for many of the plants (see Figure E2 and E3 in Annexure E).

[22] The detection of modes and troughs is done with the scipy.signals module within the popular SciPy library. It identifies local maxima by comparing each point to its nearest neighbours, and then filtering peaks based on optional criteria (in our case the default values).

the heat-based indices are more volatile and do not explicitly control for plant-specific background conditions in the same way as the status classification procedure.

4.3 Subnational indices

The geocoded nature of the plant-level data makes it possible to construct subnational indices.[23] The on-off methodology is used for this purpose. In line with the properties of cement discussed in section 4.1, three assumptions are adopted: first, plants within a province primarily supply that province; second, plants near provincial borders may supply both their home province and neighbouring provinces; and third, the productive capacity of such plants is split equally across the areas supplied to avoid double counting.

4.4 Seasonal decomposition and smoothing

After indexation, seasonal decomposition is applied to control for recurring seasonal patterns and to separate trend movements from higher-frequency fluctuations. The decomposition is additive and assumes annual seasonality, consistent with construction cycles and weather-related demand patterns.[24,25] In this paper, simple three- and six-month moving averages are used to reduce index volatility and isolate underlying trends for comparative purposes (see Annexure C).[26]

5. Validation and economic application

The resulting indices enable granular, near-real-time and high-frequency monitoring of activity in the cement industry. They therefore capture both short-term cyclical fluctuations at the plant level and broader structural developments in the sector.

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23 While plant-level data remain valuable, it is cumbersome to create indices and infer trends when indices are created using the status classification method as above.

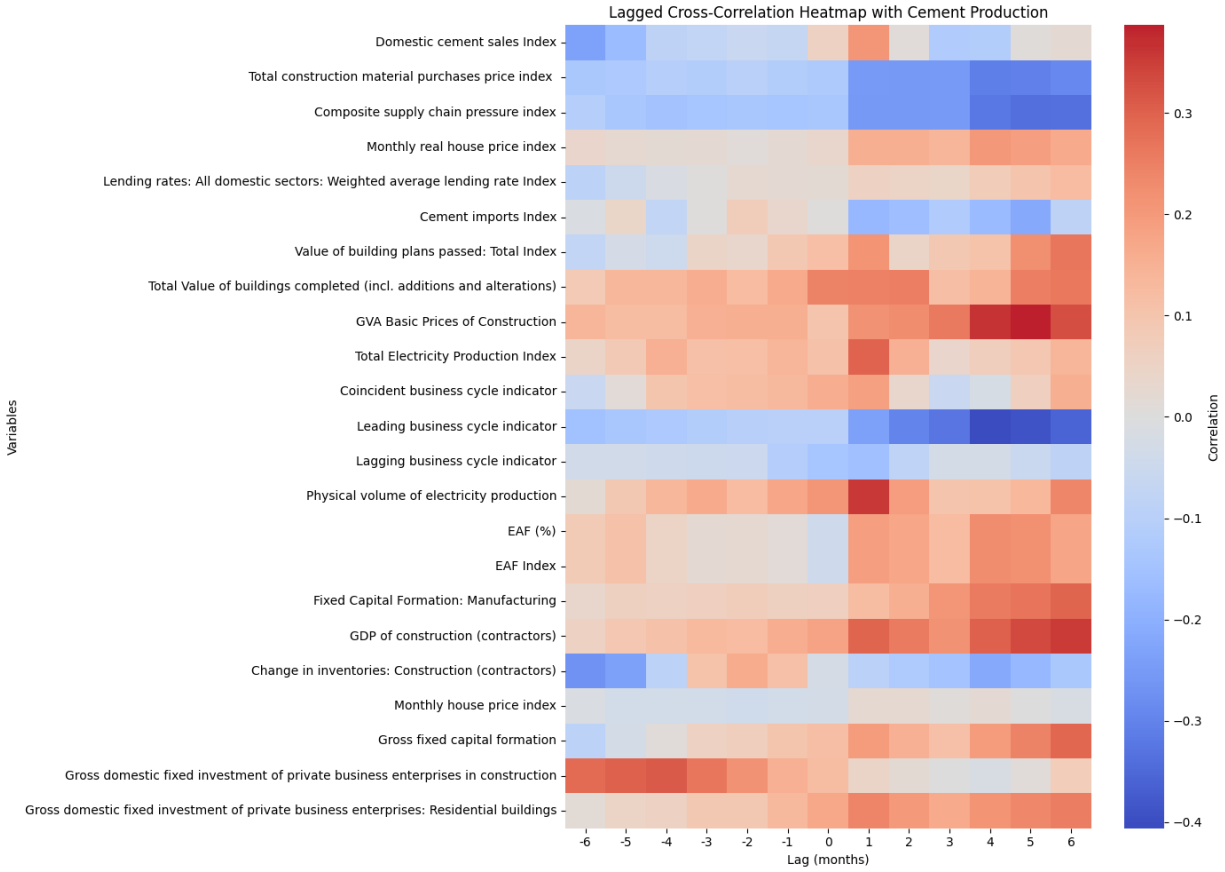
24 That means a period of 12 for the monthly indices and 73 for the five-daily indices.

25 Seasonal decompositions are applied using statsmodels, a popular time-series library for Python.

26 While filtering techniques were considered as alternative methods for extracting underlying trends, the objective of this paper is to present a transparent, easily replicable, robust and assumption-light indicator. A three-month moving average was therefore adopted to reduce short-term volatility while preserving the timeliness of the series, and a six-month moving average is also presented to illustrate broader underlying developments. This is further outlined in Annexure C.

Figure 3 presents the leading, coincident and lagging relationships between national cement production activity and a range of other construction-related indicators across alternative lag structures. Red indicates a positive correlation, while blue indicates a negative correlation. Colour intensity reflects the magnitude of the correlation, and the x-axis denotes the lag length. A strong correlation at positive lags implies that the comparator series tends to lead cement production activity.

Figure 3: Cement production cross-correlations



Source: Own calculations. Stats SA and Eskom.

Note: EAF is the energy availability factor of Eskom plants.

The cross-correlation patterns are broadly intuitive. The composite supply-chain pressure index (third from the top) is negatively associated with cement production activity, particularly at positive lags, suggesting that increases in supply-chain pressures tend to precede weaker cement activity. Electricity production (tenth from the top) is also positively related to cement activity, with the strongest association appearing at short positive lags, consistent with the dependence of cement production on energy availability. Construction GVA at basic prices and construction gross

domestic product (GDP) are strongly positively correlated with cement production activity, particularly from the four-month lag onward. The leading business cycle indicator shows a similarly strong, but negative, correlation. Gross fixed capital formation by private business enterprises in construction (second from bottom) is positively related at negative lags, suggesting that cement production activity may lead this measure. By contrast, the index displays only limited evidence of strongly coincident behaviour with other indicators, aside from some overlap with the value of buildings completed, including additions and alterations.

Although the correlation magnitudes are modest, d'Aspremont et al. (2023) show that similar indicators can improve the nowcasting of both cement production and broader construction activity (see Annexure D). The cement activity index is therefore best viewed as a timely source of information on construction sector conditions that becomes available substantially earlier than conventional statistics.[27] This is discussed further in section 5.3. Taken together, the cross-correlation evidence and the structural characteristics of the series suggest several practical uses for the indices.

5.1 Timely insights into construction sector activity

Figure 3 suggests that the cement production activity index is most informative when evaluated at specific lead-lag horizons rather than contemporaneously. However, the objective of this section is not to determine whether the index is a statistically or economically leading indicator. Instead, we focus on its usefulness as a real-time signal of construction sector developments. Owing to its high frequency and short publication lag, the index provides information on sectoral conditions well before most official construction statistics become available, making it a useful complement to conventional indicators for monitoring current developments.

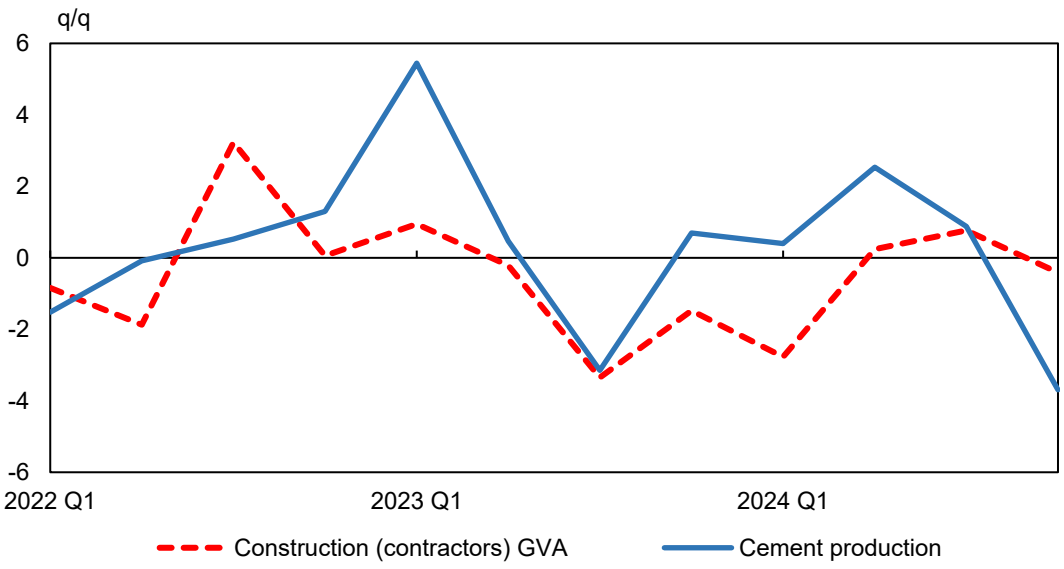
The charts below compare trends in cement production activity with official statistics. The figures indicate a clear decline in productivity in the construction sector over the sample period, which is also reflected in the satellite-derived indicator. This is evident

[27] While it is not possible to validate in South Africa due to the lack of cement production statistics, it is unlikely that there are large structural differences between American and South African cement production processes.

in both the quarterly comparison (Figure 4 and Figure 5) and the monthly index comparison (Figure 6), and is consistent with the sectoral evidence summarised in the correlation matrix above and in Annexure B. Quarterly cement production is more volatile than survey indicators suggest, and turning points do not always coincide. Notably, the monthly satellite-derived index moved earlier around the COVID-19 episode.

Figure 4 suggests that the trend in cement production broadly tracks developments in construction activity, although the relationship is not uniform across all periods. Both series generally move in the same direction, with notable synchronised slowdowns during and after 2023. This supports the view that cement production is a useful high-frequency indicator of underlying construction sector activity, given its close association with building and infrastructure projects.

Figure 4: Quarterly cement production and construction GVA

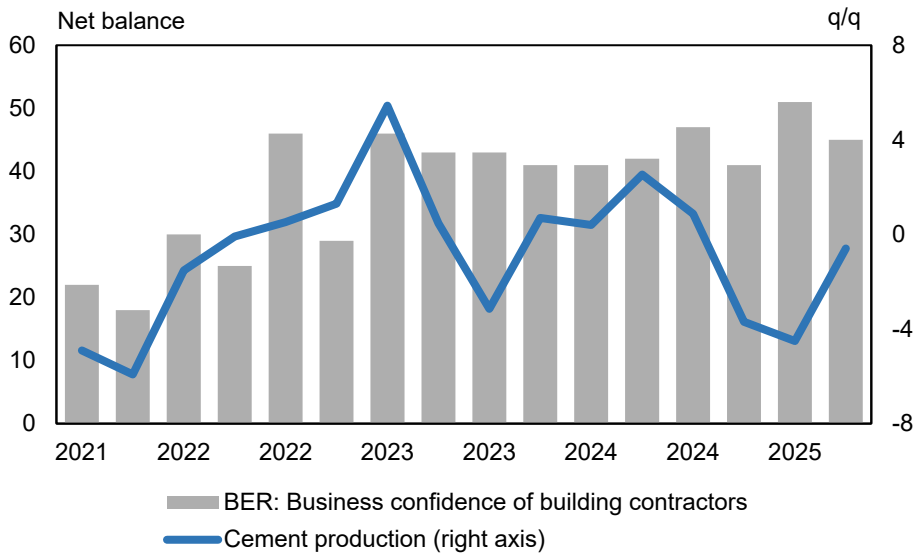


Source: SARB and Stats SA.

Figure 5 compares quarter-on-quarter growth in cement production with the BER Business Confidence Index for building contractors. The graph suggests a generally positive relationship between the two indicators, with periods of stronger contractor confidence often coinciding with, or preceding, improvements in cement production. Confidence tends to be smoother and more persistent, while cement production is

considerably more volatile, reflecting short-term influences on actual construction activity. This supports the case for using both indicators together when assessing developments in South Africa's construction sector.

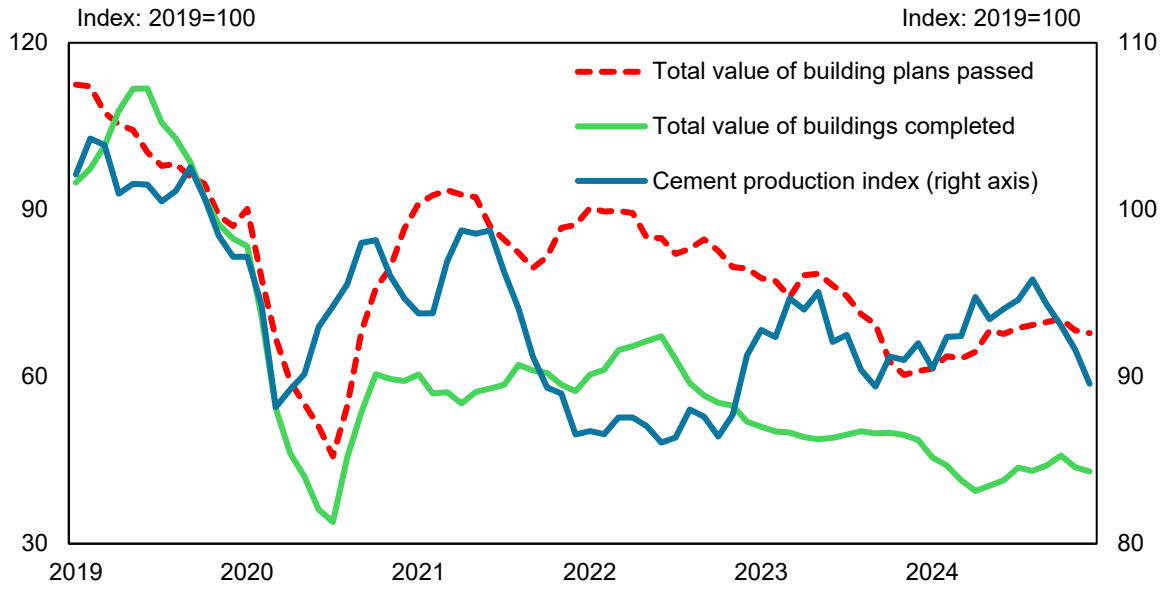
Figure 5: Quarterly cement production and construction confidence



Source: BER and SARB.

A similar pattern is visible for the monthly indicators in Figure 6, although the relative volatility is more muted. Compared with the monthly value of building plans completed and passed, the satellite-derived trend does not show a decline of the same magnitude, even though it tracks turning points and broad movements in the sector. This is consistent with the nature of the index, which reflects plant operating status rather than production volumes. In addition, the official indicators do not capture all forms of construction activity, including routine maintenance and some infrastructure projects, which may dampen the magnitude of fluctuations observed in cement production activity, especially during recessions or periods of weak growth.

Figure 6: Monthly cement production mirrors declining construction sector activity*



Source: SARB and Stats SA.

Note: *Six-month moving average applied.

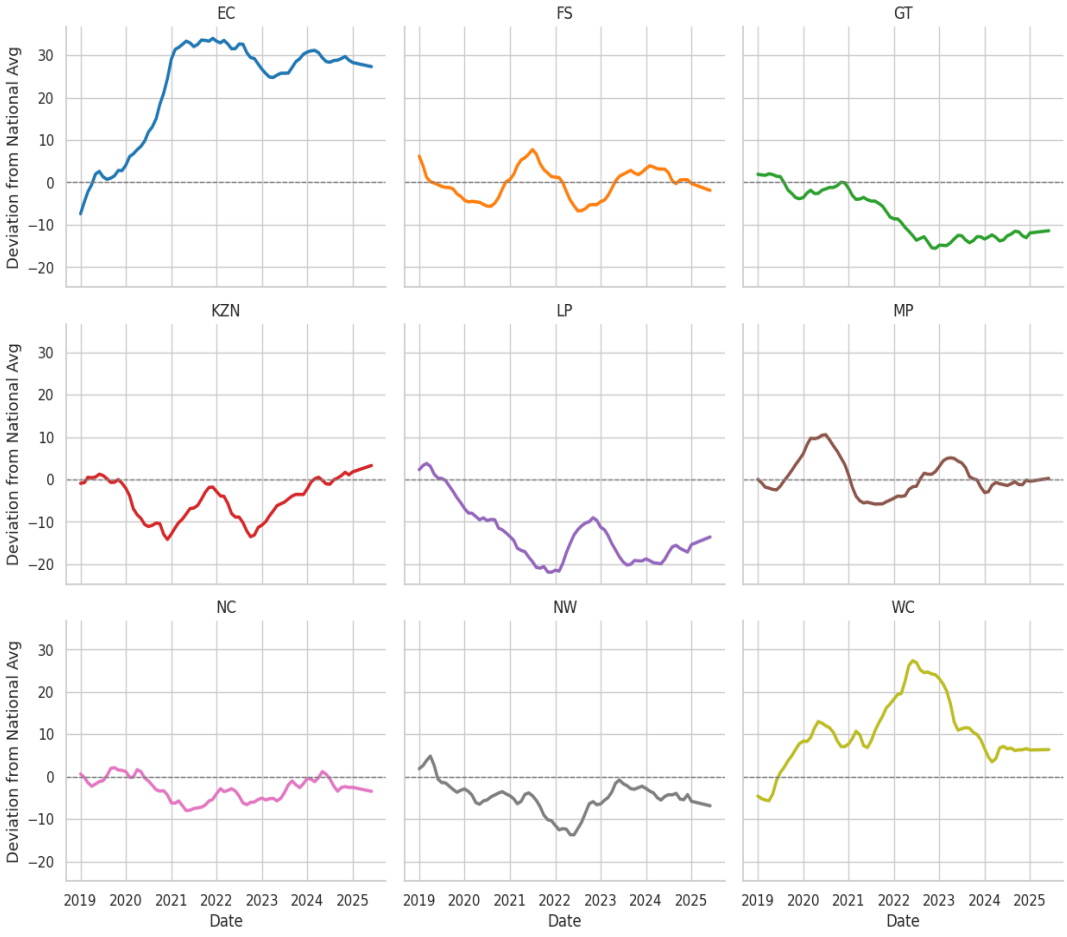
Taken together, the evidence suggests that the cement production activity index provides a useful and timely signal of developments in South Africa's construction sector. While it is not intended to replace official statistics, and turning points are not always coincident across indicators, the index broadly reflects the prolonged weakness observed in the sector and is available substantially earlier than most conventional measures. Its value therefore lies in providing near-real-time information on construction sector conditions, complementing existing indicators and enabling earlier assessment of developments between official data releases. The geocoded nature of the index also allows this monitoring to be extended beyond the national level, as discussed in the following section.

5.2 Subnational activity monitoring and event analysis

The geocoded nature of the satellite-derived indices allows for subnational monitoring of activity. This rests on the assumption that local production is closely linked to local demand, an assumption that is plausible for cement given its production and transport characteristics. Figures 7 and 8 compare provincial production activity with the national average, using 2019 as the benchmark year.

Over this period, the Eastern Cape, Western Cape and Free State are the only provinces to outperform the national average in terms of activity, implying that plants serving these provinces were classified as producing more frequently and, in relative terms, at higher levels. The Eastern Cape's relative performance partly reflects the addition of a plant during the sample period, although activity there has subsequently weakened. Gauteng, Limpopo and North West have generally remained below the national average. Figure 8 highlights the cumulative deviation from the national average between 2019 and 2025 and therefore provides a snapshot of relative provincial performance over the period.

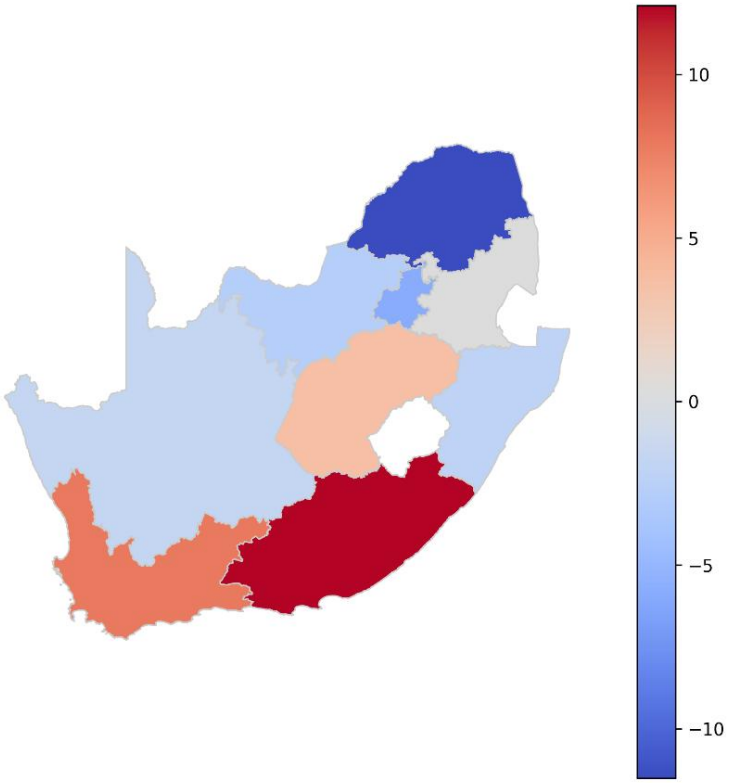
Figure 7: Regional cement plant activity trends relative to South Africa's average (2019 benchmark)



Source: SARB.

Note: 2019=100.

Figure 8: Regional activity deviation (%) from national average (2019 to 2025)

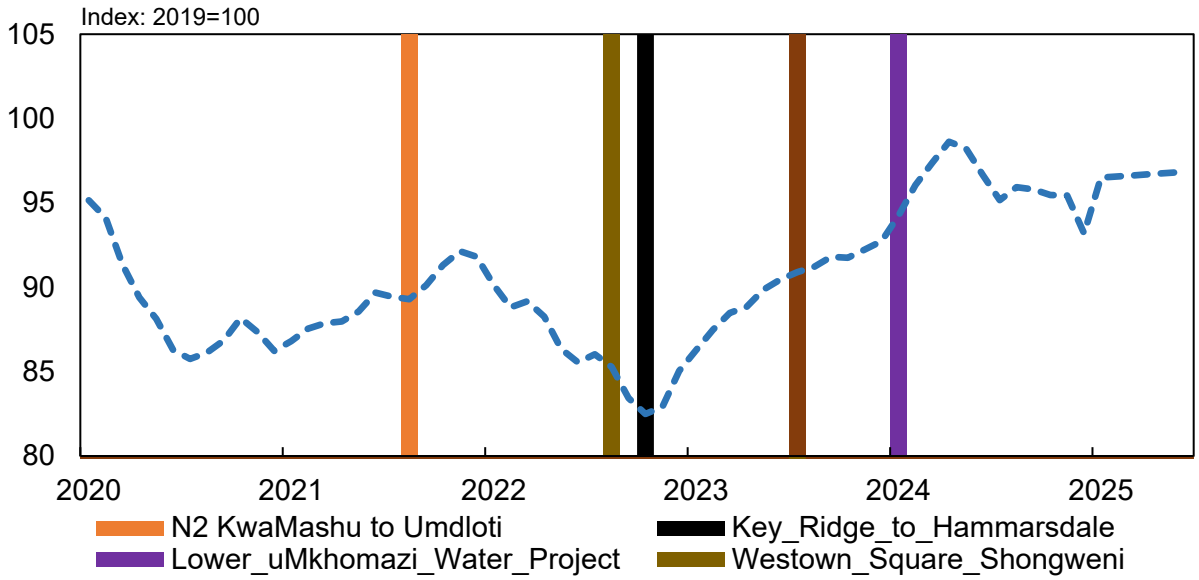


Source: SARB.

Note: 2019=100. Red indicates higher production activity deviation from national average.

Figure 9 provides an illustrative example based on selected government infrastructure project start dates in KwaZulu-Natal, a province where production activity has recovered somewhat in recent years but remains below 2019 levels. Although the evidence is descriptive and should not be interpreted as causal, the timing of selected project commencements appears broadly aligned with increases in cement production activity.

Figure 9: KwaZulu-Natal cement production and select infrastructure project construction start dates*



Source: SARB.

Note: *Dates sourced from various news articles.

5.3 High-frequency analysis and real-time shock monitoring

A new observation for each index can be produced with a lag of at most five days. This provides timely information on current production and demand conditions in the construction sector. Unlike most official construction sector statistics, which are released monthly or quarterly and with publication lags, the cement production activity index provides near-real-time information on developments in the sector. As such, it can complement existing monitoring frameworks by providing an additional high-frequency signal of construction activity between official data releases.

D'Aspremont et al. (2023) show that similar indicators can improve the nowcasting of both cement production and broader construction activity (see Annexure D). Therefore the cement activity index is best viewed as a leading indicator in terms of publication timing, not economic activity: it is available earlier, but does not lead the economy.

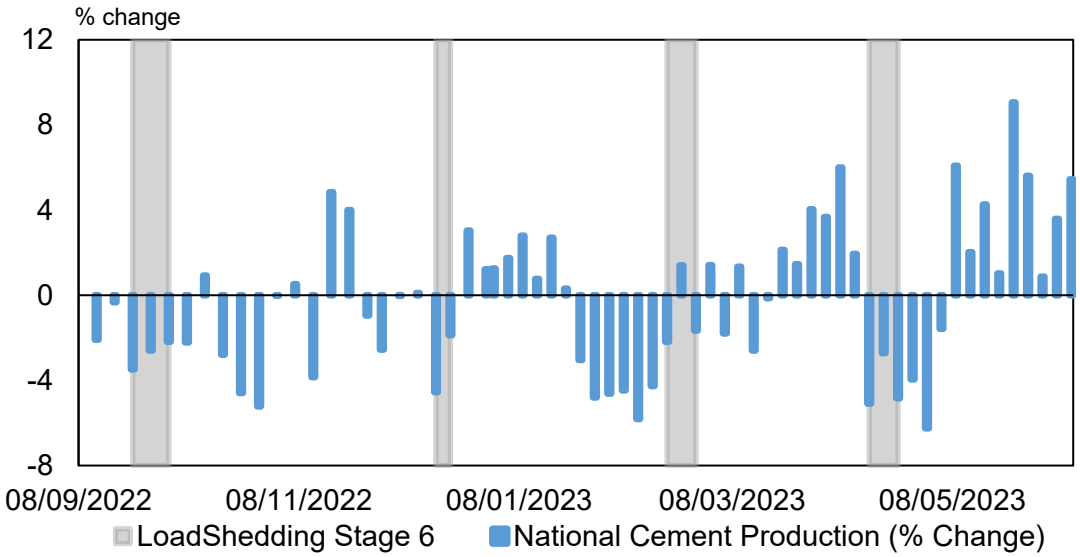
At the same time, the indices evaluated in d'Aspremont et al. (2023) differ from those developed here, most notably in frequency (daily rather than five-daily). Even so, the SARB indices could be resampled to daily frequency to approximate the original

framework, while also benefitting from broader plant coverage, a more robust status classification procedure and the availability of province-level indices. Formal evaluation of forecasting performance within SARB modelling and nowcasting frameworks is left for future research.

Beyond potential forecasting applications, the high-frequency nature of the cement production activity indices makes them useful for analysing turning points and monitoring related developments in the real economy. Potential applications include tracking the effects of severe load-shedding episodes, logistics disruptions, infrastructure rollouts and other shocks that affect construction activity. Because the index is available within days rather than weeks or months, it provides information that would otherwise be unavailable from conventional construction sector statistics. Its value is therefore likely to be greatest when used alongside other high-frequency indicators and as an input into broader assessments of current economic conditions.

Figure 10 provides an example by comparing five-daily changes in cement production activity with periods of stage 6 load-shedding. Although the exercise is illustrative, it demonstrates the potential for timely and geographically disaggregated analysis of shocks to production activity.

Figure 10: Five-daily cement production percentage changes and stage 6 load-shedding periods



Source: SARB and Eskom.

Overall, the cement production activity indices represent a useful addition to the SARB's analytical toolkit. They constitute the first indicator of this kind to be developed and maintained within the modelling ecosystem and provide timely nuance to assessments of construction sector activity.

6. Conclusion

This paper has described the construction and proposed use of high-frequency monitoring tools for South African cement production activity, building on the pioneering work of d'Aspremont et al. (2023). The resulting indices are both high frequency and spatially granular, and they constitute the first in-house indicator derived from satellite imagery developed for the SARB. They rely exclusively on publicly available Sentinel-2 imagery and were produced using an imagery-processing pipeline that could be adapted for other applications.

The indicators track plausible trends in national and regional construction activity, co-move with established indicators, and are supported by evidence from related studies showing gains in real-time tracking of cement production and construction activity. They can therefore complement existing statistics on the construction sector while enabling temporally and spatially granular analysis because of their geocoded structure and very short publication lag. These features make the indices a useful early signal in a sector characterised by slow data releases and limited spatial disaggregation. They can also complement existing SARB monitoring and analytical processes, including regional activity analysis and related toolsets, by adding timely information to assessments of real economic conditions.

The indices should nevertheless be interpreted with appropriate caution. They measure plant operating status and activity rather than production volumes, and the uneven spatial distribution of plants complicates direct interregional comparisons. In addition, smoothing is required to identify longer-term trends, which makes the choice of smoothing method relevant for practical use. The credibility of the indices also depends on maintaining an up-to-date list of active plants, as changes in plant entry, closure or mothballing affect the interpretation of longer-term developments in demand and activity. Future work should therefore focus on these issues and on further integrating the indices into broader modelling and analytical frameworks.

Annexures

Annexure A: The cement production process

Producing cement requires six steps: (i) extracting materials; (ii) grinding, proportioning and blending the mix of raw materials; (iii) pre-heating; (iv) clinker production using the rotary kiln; (v) cooling, further blending and grinding; and (vi) packing and shipping. Rotary kilns – large, specialised 'ovens' – are used to facilitate chemical reactions at high temperatures and allow for observation using satellite imagery.

Annexure B: The South African cement industry

Since 1994, six major competitors have dominated the industry: PPC Cement (22% of market share in 2016), Natal Portland Cement (NPC, 15%), Sephaku (12%), AfriSam (9%), Lafarge-Holcim (9%) and Mamba Cement (5%). Mamba Cement entered in 2016, with Sephaku entering in 2006. Imports made up 5% of the total share in 2016, with the remaining production allocated to third-party blenders (Ige et al. 2022; Lowitt 2020). However, cement imports have increased in recent years, with Vietnam, Mozambique and Namibia among the main suppliers (Industry Insight 2024, 2025).

According to a recent report by Onestone Consulting, South African cement production has been in decline for several years, with production capacity utilisation of 55.4% in 2022 across the six primary producers (Onestone Consulting 2022). This finding was reinforced by the Chief Executive Officer of Cement and Concrete South Africa, Bryan Perrie, who argued that insufficient public infrastructure spending has constrained cement production, which is operating at around 50% of capacity (GIBS 2023a). A report released by the Centre for African Management and Markets in 2023 states that South Africa's annual production capacity was around 22 million tonnes in 2023, with only 13 million tonnes being utilised. The report also outlines the importance of maintaining competitiveness in the local market, given the long and capital-intensive domestic value chain (GIBS 2023b). The 2024 Global Cement Report echoes many of these statistics, although with somewhat different numbers. According to that report, cement production in South Africa can be summarised as follows: capacity utilisation is approximately two-thirds, with total capacity of 20 Mt/yr and output of 12 Mt/yr. Cement imports amounted to about 1 Mt/yr in 2024, of which 10–15% went to the Western Cape. Import sources include Vietnam, Mozambique, Namibia, Saudi Arabia

and the United Arab Emirates. There is also new capacity in development, with PPC planning a capacity upgrade to 1.5 Mt/yr at the Riebeek plant. The Simuma plant in KwaZulu-Natal is also slated for a capacity upgrade. In terms of ownership, in 2024 Chinese firm Huaxin Cement bought NPC, which owned three South African plants, while Afrimat purchased Lafarge South Africa.

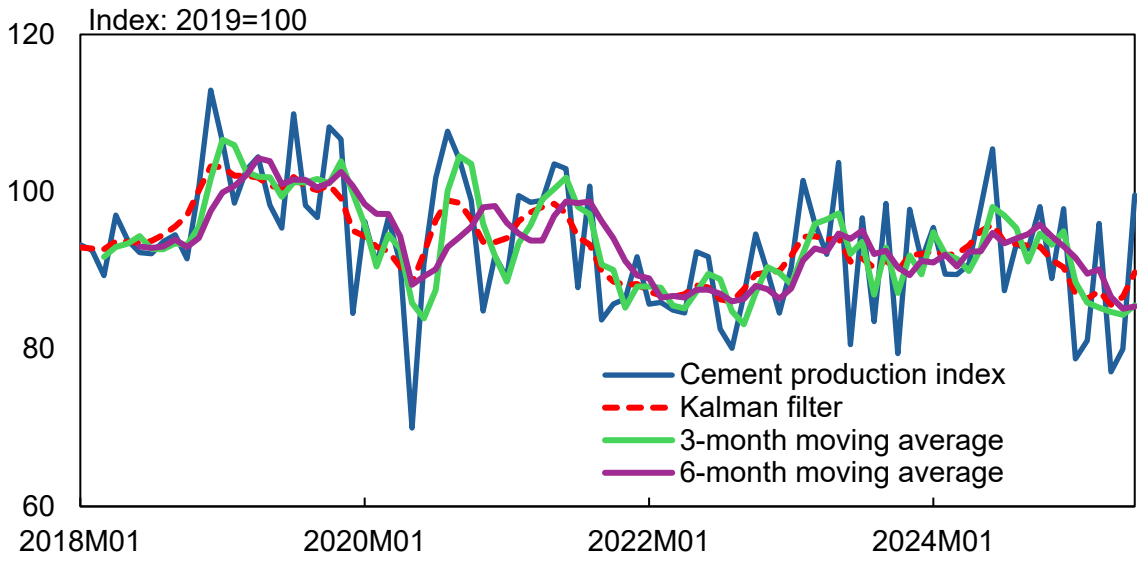
Annexure C: Considerations for interpreting the cement production index

- The index is based on the classification of plant production status and should thus be treated as an indicator of operational activity and not production volumes.[28]
- Relative to some standard macroeconomic indicators, the index may be less sensitive to short-term fluctuations because it captures a baseline level of demand associated with maintenance activity and public infrastructure projects.
- The index will reflect structural change accurately only if the list of active plants is updated on an ongoing basis. During the sample period, one additional plant in the Eastern Cape came into operation and was incorporated into the index.
- Because cement plants are costly to start up and shut down, production status tends to adjust gradually. The signal therefore captures moderate changes in demand rather than very short-lived fluctuations.
- The indicator does not measure construction value added in full, as it does not capture labour input or related services.
- Cement plants are not evenly distributed across space, with some provinces hosting more plants and greater productive capacity than others. Comparisons across subnational indices should therefore be interpreted with caution.
- We explored the use of a Kalman filter to extract the underlying signal from the index. However, the resulting estimates tended to smooth over certain turning points and short-term shifts in activity, reducing the responsiveness of the indicator (see Figure C1). Consequently, for simplicity, transparency and ease of interpretation, this paper adopts a moving average approach. Specifically,

[28] There is, however, evidence that plants with larger production capacities also have higher heat footprints, as seen in Annexure E: Figure E1.

three- and six-month moving averages are applied to reduce short-term volatility while preserving the underlying trend in the data for comparative analysis.

Figure C1: Smoothing comparisons



Annexure D: Nowcast benchmark framework

For the South African case, d'Aspremont et al. (2023) report the following benchmark findings:

- Ordinary least squares (OLS) models that include the satellite-derived index outperform random-walk (RW) and autoregressive (AR) benchmarks when nowcasting non-metallic mineral products. See Table D1.
- The satellite-derived indicator also outperforms alternative nowcasting indicators, including the Purchasing Managers' Index (PMI), Google Trends and building permits, when predicting non-metallic mineral products. See Table D2.
- The indicator likewise outperforms random-walk and autoregressive benchmarks, as well as the alternative nowcasting instruments, when nowcasting broader construction sector activity. See Table D3.

The tables reproduced below from d'Aspremont et al. (2023) report the relative out-of-sample performance of the satellite-based indicator for South Africa and compare it with the global average. Negative values indicate better relative accuracy. The results

suggest that South Africa benefits materially from these indices, with forecast gains in several cases exceeding the global average.

Table D1: Relative RMSE (out-of-sample) OLS comparison against benchmarks

	OLS vs RW	OLS vs AR	Plants covered	OLS (RMSE level)
South Africa	−27.6%**	−44.9%***	11	1.40
Global average	−24.7%	−13.5%	47	0.41

Source: d'Aspremont et al. (2023).

Note: *, ** and *** represent values that are statistically significant at the 10%, 5% and 1% levels respectively.

Table D2: Relative RMSE (out-of-sample) comparison against alternative indicators

	Satellite vs PMI	Satellite vs Google Trends	Satellite vs building permits
South Africa	−13.6%*	−12.6%	−58.4%***
Global average	−8.2%	−8.6%	−17.0%

Source: d'Aspremont et al. (2023).

Table D3: Relative RMSE (out-of-sample) for construction sector nowcasts

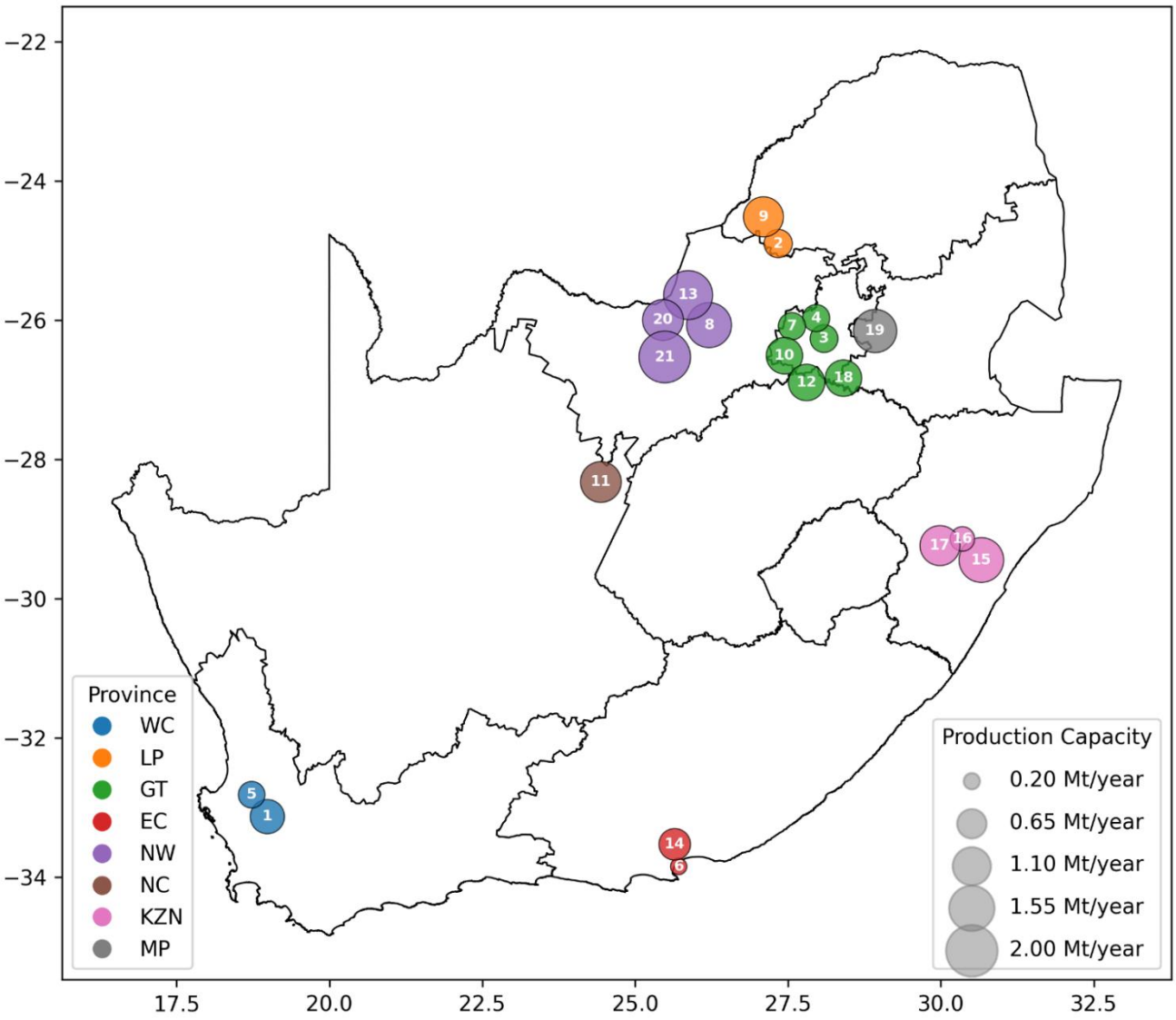
	Satellite vs RW	Satellite vs AR	Satellite vs PMIs	Satellite vs Google Trends	Satellite vs permits
South Africa	−28.4%*	−2.8%	−4.3%	−5.1%	−2.9%
Global average	−22.1%	−7.0%	−2.7%	−6.2%	−8.1%

Source: d'Aspremont et al. (2023).

These results suggest that such indices can improve the accuracy of modelling exercises.

Annexure E: Plant-level descriptive statistics

Figure E1: Plant locations by province and production capacity



Source: Own calculations.

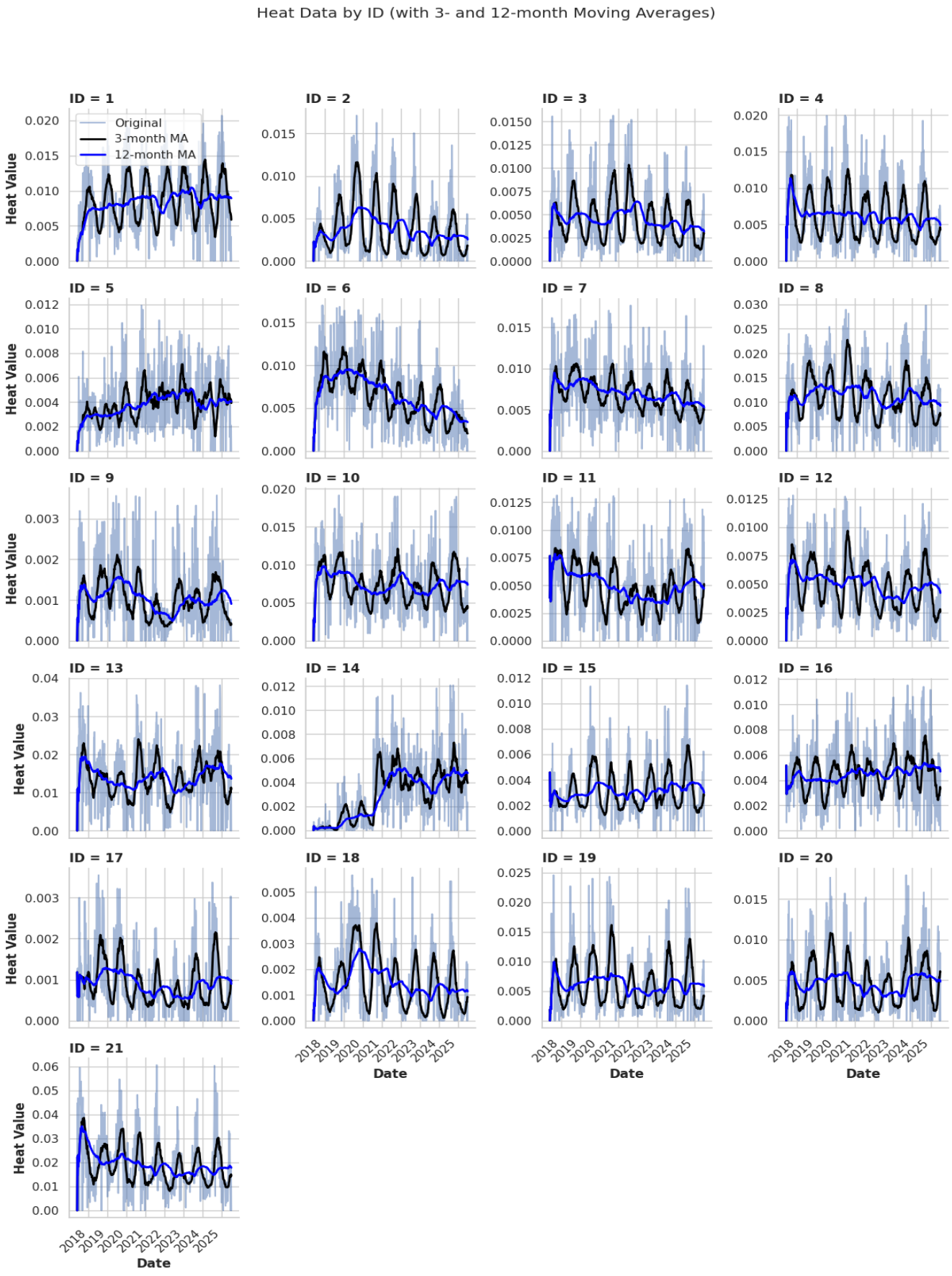
Note: Plant locations are approximate. WC: Western Cape; LP: Limpopo; GT: Gauteng; EC: Eastern Cape; NW: North West; NC: Northern Cape; KZN: KwaZulu-Natal; MP: Mpumalanga.

Table E1: Descriptive statistics for cement production plants

Plant ID	Plant name	Company	City	Province	Production capacity (million metric tonnes p.a.)
1	De Hoek	PPC	Piketberg	WC	0.88
2	Dwaalboom	PPC	Adriaanshoop	LP	0.6
3	Hercules	PPC	Pretoria	GT	0.58
4	Jupiter	PPC	Johannesburg	GT	0.55
5	Riebeek	PPC	Riebeek West	WC	0.53
6	Gqeberha	PPC	Gqeberha	EC	0.2
7	Meyerton	PPC	Meyerton	GT	0.567
8	Slurry	PPC	Slurry	NW	1.52
9	Mamba	Mamba	Krokodilkraal	LP	1.2
10	Vanderbijlpark	AfriSam	Vanderbijlpark	GT	1
11	Ulco	AfriSam	Ulco	NC	1.25
12	Roodepoort	AfriSam	Roodepoort	GT	1
13	Dudfield	AfriSam	Dudfield	NW	1.8
14	Coega	Cemza	Coega	EC	0.75
15	Simuma	NPC	Port Shepstone	KZN	1.5
16	Newcastle	NPC	Newcastle	KZN	0.45
17	Durban	NPC	Durban	KZN	1.2
18	Randfontein	Afrimat	Randfontein	GT	1
19	Delmas	Sephaku	Delmas	MP	1.4
20	Bodibe	Sephaku	Bodibe	NW	1.25
21	Lichtenburg	Afrimat	Lichtenburg	NW	2

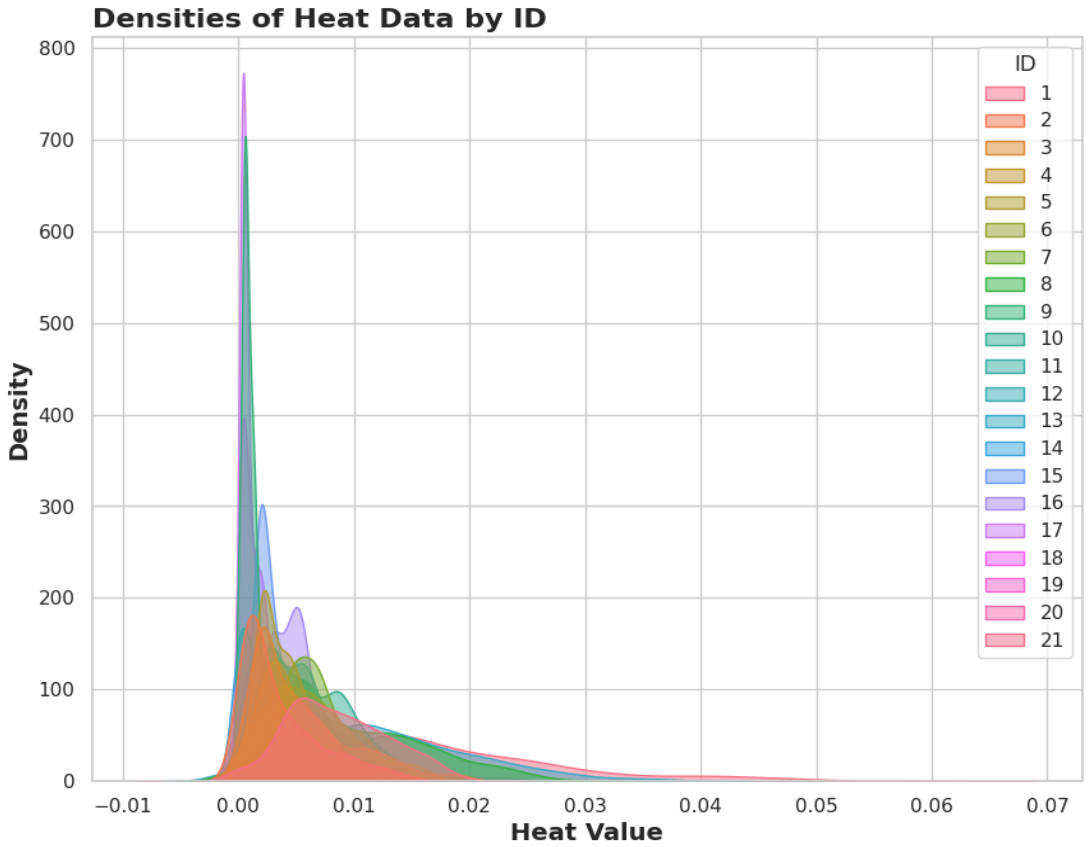
Source: Industry research.

Figure E2: Heat values by plant



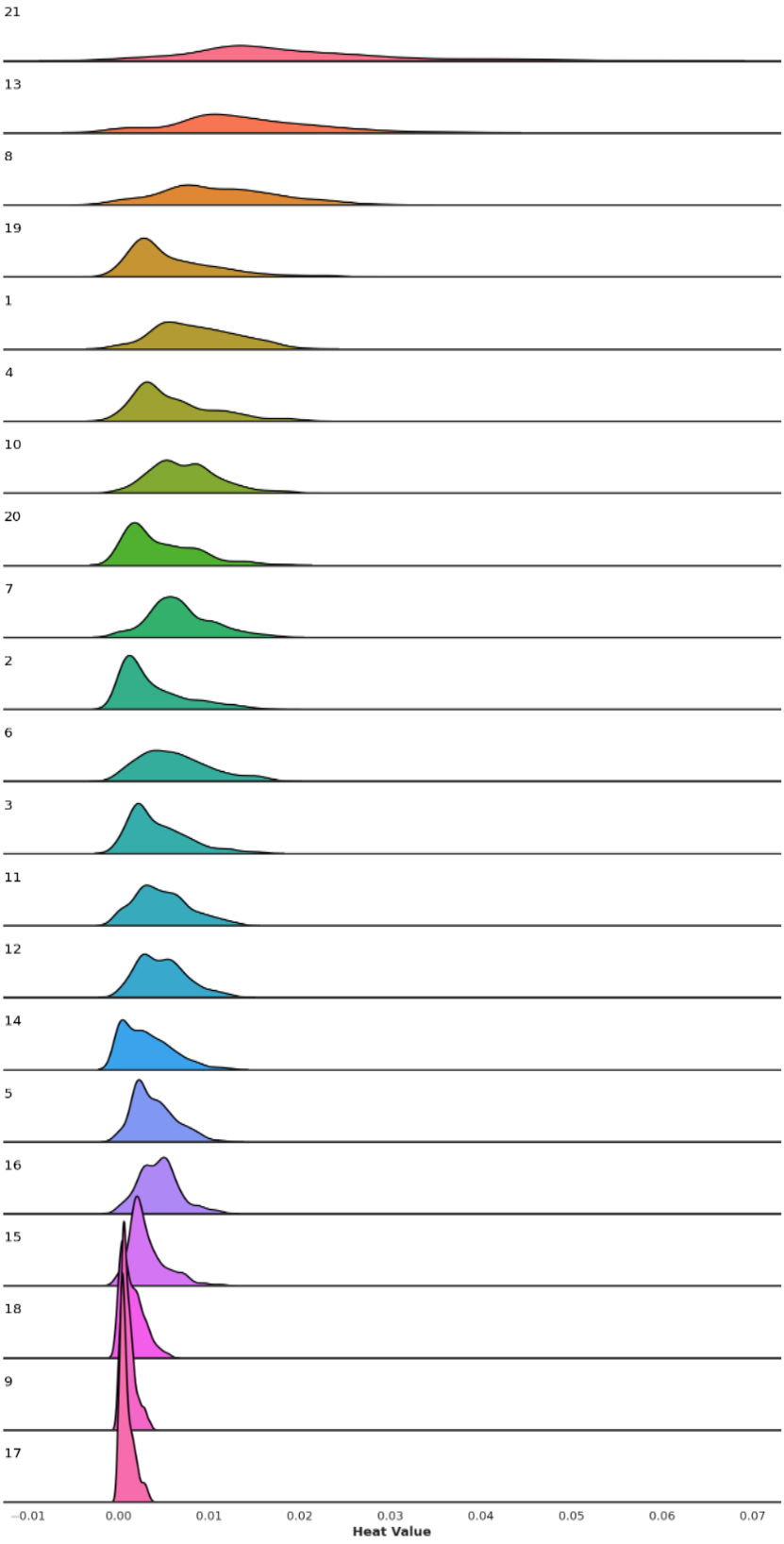
Source: Own calculations.

Figure E3: Plant-level heat densities – all plants



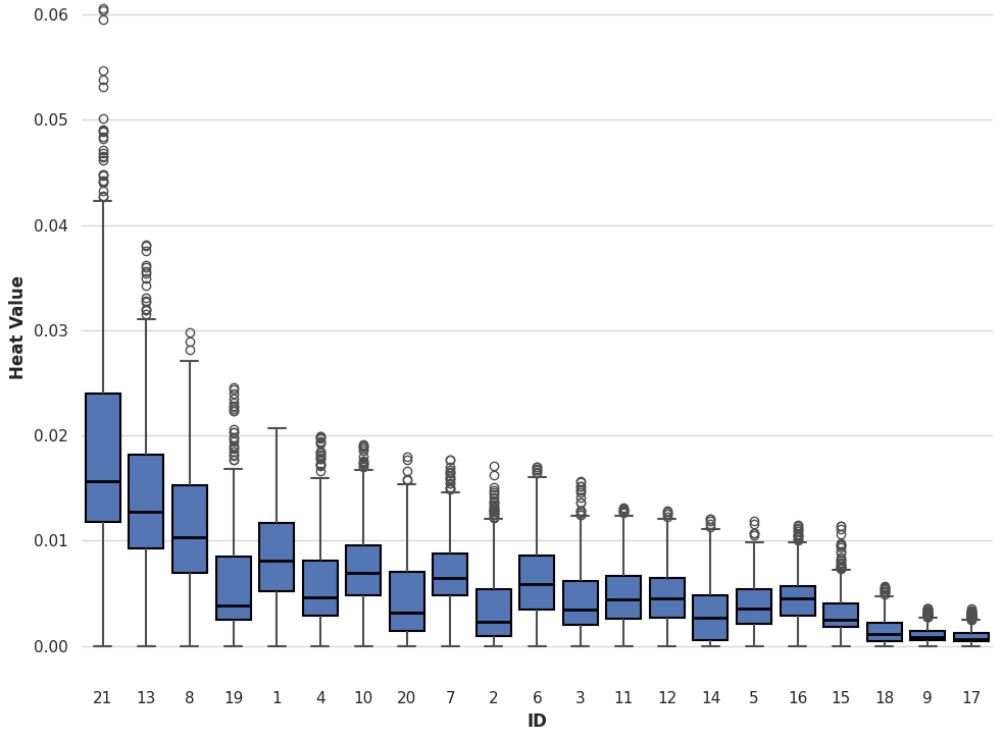
Source: Own calculations.

Figure E4: Heat data distributions, by plant ID



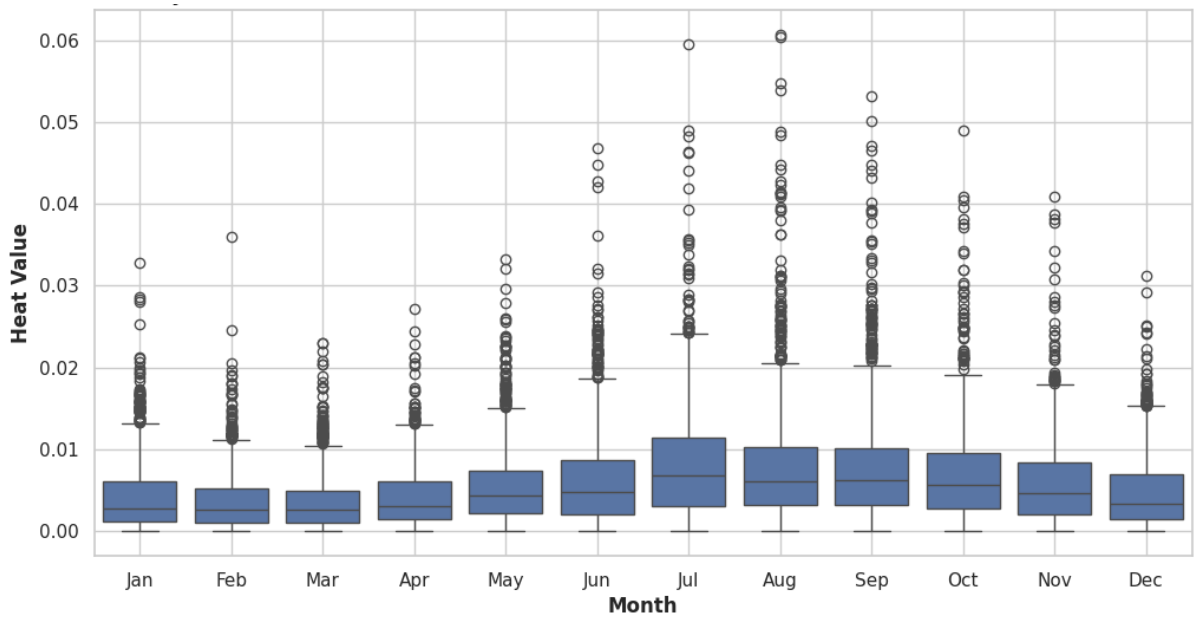
Source: Own calculations.

Figure E5: Heat data boxplots, by plant ID



Source: Own calculations.

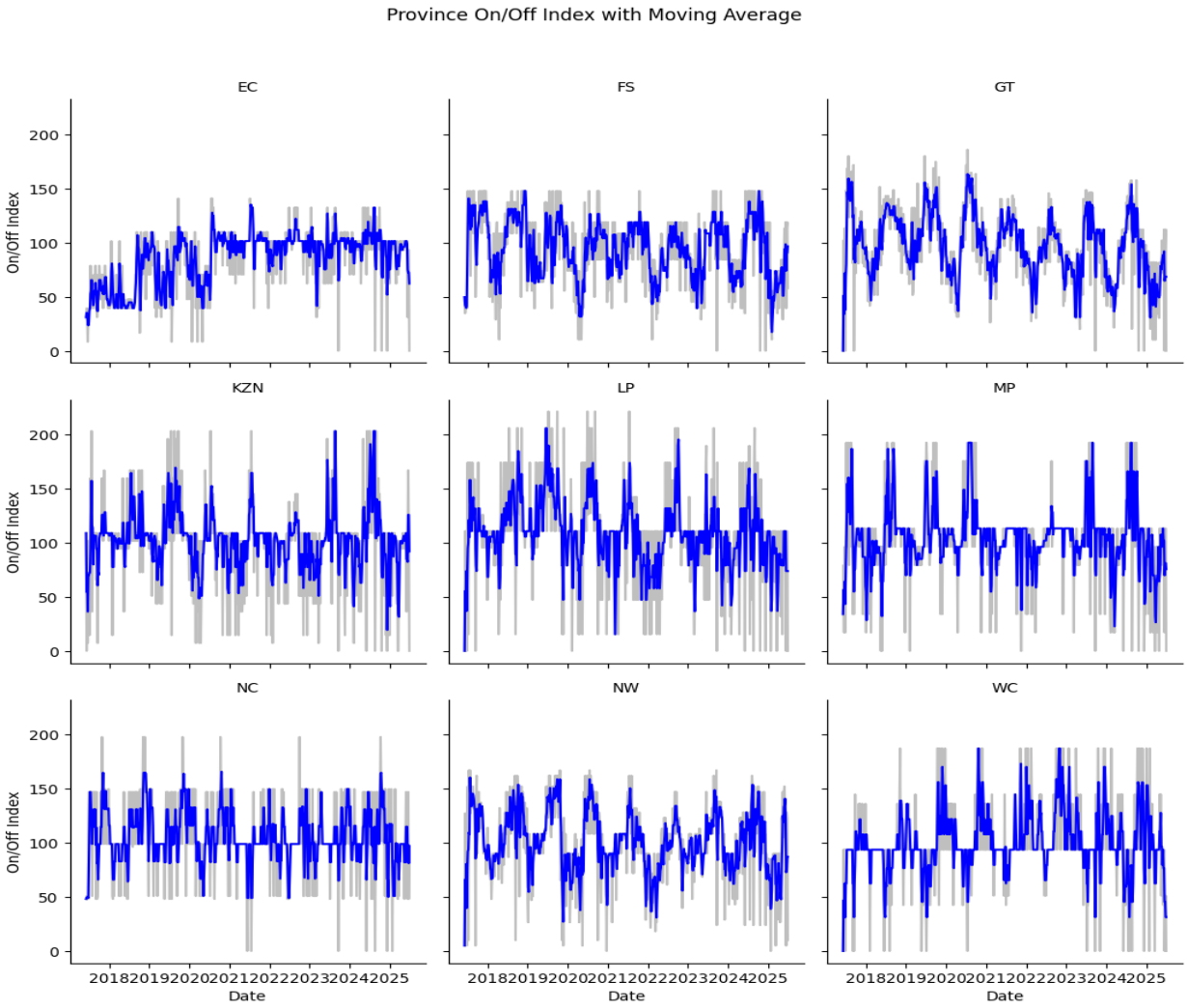
Figure E6: Monthly distribution of heat detection across all plants



Source: Own calculations.

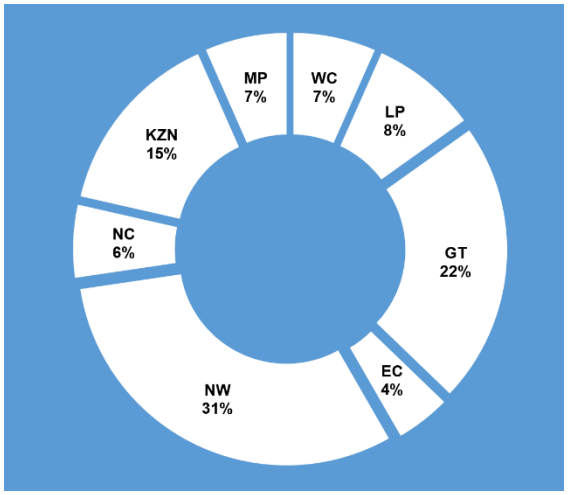
Annexure F: Province-level statistics

Figure F1: Provincial cement production activity indices



Source: Own calculations.

Figure F2: Proportion of production capacity by province



Source: Industry research.

Annexure G: Heat-detection algorithms

The equations below outline the algorithms used to detect 'hot' pixels (1), 'very hot' pixels (2) and 'extremely hot' pixels (3). These equations rely on relative thresholds that were calibrated by Massimetti et al. (2020).

$$\frac{\rho_{12}}{\rho_{11}} \geq 1.4 \; and \; \frac{\rho_{12}}{\rho_{8a}} \geq 1.2 \; and \; \rho_{12} \geq 0.15 \tag{1}$$

$$\frac{\rho_{11}}{\rho_{8a}} \geq 2 \; and \; \rho_{11} \geq 0.5 \; and \; \rho_{12} \geq 0.5 \tag{2}$$

$$[\, \rho_{12} \geq 1.2 \; and \; \rho_{8a} \; \leq 1] \;\; or \; [\, \rho_{11} \geq 1.5 \; and \; \rho_{8a} \; \geq \; 1] \tag{3}$$

To control for the detection of false positives, d'Aspremont et al. (2023) applied the Autonomous Sciencecraft Experiment (ASE) method based on a specific spectral gradient (g) threshold being exceeded, as below:

$$g = \frac{\rho_{12} \; - \; \rho_{11}}{\rho_{12} \; + \; \rho_{11}} \tag{4}$$

For the country-specific threshold, as well as the gradient threshold g above, we apply the threshold of 0.06, which is at the upper band of the threshold range. Although this algorithm is generally robust, false positives remain a concern. The ASE algorithm addresses this by cross-checking pixels identified as 'hot' by HOTMAP against a country-specific gradient threshold.[29] As an additional robustness check, outliers are identified for each plant using the interquartile range method after the application of the heat-detection algorithms, and flagged outliers are replaced with *NaN*. For more information on this process, refer to the original paper by d'Aspremont et al. (2023).

[29] The gradient threshold we chose for ASE is 0.06 over the entire sample, which is the upper limit as empirically tested by d'Aspremont et al (2023). Generally, the higher the threshold, the stricter the condition to meet for a pixel to be classified as 'hot'. It would be useful to vary this threshold in future studies, according to geographic region.

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