
# Streamlined Models of CMOS Image Sensors Carbon Impacts

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***Abstract*— With the escalating concern about global warming, the environmental impact of electronic devices must be scrutinized. Life Cycle Assessments (LCA) reveal that Integrated Circuits (ICs) are the primary contributors to Greenhouse Gas emissions in these devices. However, performing an inventory to determine the IC's impact is a complex task due to missing data. This paper proposes a multi-level set of models that leverage available information while considering the specificities of CMOS Image Sensors (CIS).**

***The proposed models are applied to sensors manufactured by STMicroelectronics and Sony, and the results are compared with existing LCA results, such as those from Fairphone. This approach provides a more comprehensive understanding of the environmental impact of CIS, contributing to the broader goal of reducing the carbon footprint of electronic devices.***

***Keywords*— Carbon Footprint, CMOS Image Sensors (CIS),Greenhouse Gas Emissions, Life Cycle Assessment (LCA)***

## I. Introduction

The escalating carbon impact of the electronics industry underscores the global urgency to adhere to the 2050 Paris Agreement [1]. As the environmental footprint of electronic devices continues to grow, it becomes imperative to enhance their sustainability.

The total silicon area in a mobile phone continues to expand. This trend is partly due to the increasing area and number of CIS in terminals. The environmental impact of these sensors must be seriously considered as they will start to contribute significantly to the Global Warming Potential (GWP) of a device. Gaining access to actual information to perform a proper LCA [2] inventory is often not achievable. We propose a methodology that relies on existing data from the literature coupled with available technical information. We demonstrate how this can be leveraged to assess the environmental impact of CIS in a simple and efficient manner.

## II. Methodology

The fabrication phase of semiconductor devices is known to have a significant share in the GWP impact. However, finding precise data to estimate the carbon impact of a silicon device is not always possible. This study will focus on this aspect to provide simple models to determine this part of the carbon contribution of a given CIS:

### *1) Area model:*

When most of the information is missing, one simple way to estimate the carbon impact of a CIS is to only rely on the silicon area (noted S). We can use model (1) with a global average factor $Ks_{avg} = 3kg/mm^2$ , that is independent from the factory location and the type of process used.

$$E_{Fab} = S \cdot K_{S_{avg}} \qquad (1)$$

*2) Area + Vendor:*

Adding the vendor's name comes with valuable information about the fabrication site, as it helps to identify the corresponding energy mix. The table I shows estimated factory location based on official communication from the main vendors [3], and the corresponding carbon intensity [4].

TABLE I. LOCATION AND ASSOCIATED ENERGY INTENSITY PER CIS VENDOR

| Name | Share | Location | Intensity (g/kWh) |
|---|---|---|---|
| SONY | 42% | Japan | 435 |
| Samsung | 19% | South Korea | 438 |
| OmniVision | 11% | China | 534 |
| ST Micro | 6% | France | 85 |
| Onsemi | 6% | USA | 368 |
| SK Hynix | 5% | South Korea | 438 |

However, only a fraction of the GWP is dependent on the local energy mix as expressed in the carbon intensity T loc. The fabrication of the silicon substrate in the form of silicon ingots is done by an external provider, and so are the chemicals used for the fabrication of the image sensors. For this reason, the impact of the electrical energy Es used for the fabrication of the device must be separated in the equation (2) from the impact of the chemicals and raw materials K. As shown in [5], the impact is dependent on the technology node used to manufacture the device. With no additional prior knowledge, an average technology can be chosen. We propose an average technology of 65nm for $K_{avg}$ and $E_{S_{avg}}$.

$$E_{Fab} = S \cdot (E_{S_{avg}} \cdot T_{loc} + K_{avg}) \quad (2)$$

The work provided by Boyd [6] has been used to determine the values for Es and K shown in table II.

TABLE II. LOCATION AND ASSOCIATED ENERGY INTENSITY PER CIS VENDOR

| Process node ($nm$) | Materials ($gCO_2e/mm^2$) | Electrical energy ($Wh/mm^2$) |
|---|---|---|
| 180 | 16.4 | 87 |
| 130 | 11.7 | 77 |
| 90 | 14.5 | 85 |
| 65 | 16.0 | 99 |
| 45 | 19.2 | 121 |
| 32 | 20.1 | 129 |

*3) Area + Vendor + Technology node:*

When the process node is known, we obtain a more precise model of the GWP for the imaging device, which gives model (3):

$$E_{Fab} = S \cdot (E_{S_{nm}} \cdot T_{loc} + K_{nm}) \quad (3)$$

## III. RESULTS

In the Fairphone4 LCA [7], the "Rear cameras module", made up of two Sony IMX582, is reported to account for a total of 2460 $gCO_2e$. The present methodology has been applied to this sensor to determine the missing parameters. We made approximations of the surface of $34\ mm^2$. Given the component's recent release date (2018), a 65 nm process can be considered a conservative choice. Regarding the factory location, Sony being the vendor, the Japanese Carbon Intensity will be used. Recent sensors use at least 2 wafers to maximize light sensitivity while keeping the component's footprint small. If we assume the IMX582 to have a logic section below the sensitive area, we need to add the impact of this second layer to the estimation given above. For this logic portion of the device, it is safe to assume a 45 nm technology, with the actual design probably being in a more recent technology. This gives a total of 4451 g for the full component. Doubling this value for the two devices, **the total estimated embodied carbon is 8901 g**. This result is substantially different from the value reported in Fairphone4 LCA.

## IV. CONCLUSION

Our study suggests that the carbon impact of CIS is likely underestimated. The increasing number of cameras and their growing complexity have rapidly shifted the significance of smartphone cameras to the level of SoC or memory. This underscores the need for more readily available data. While publicly available models exist, like the IMEC [8] database, they lack transparency and cannot be adapted to other needs. If CIS manufacturers, and other semiconductor manufacturers, were to provide more data, assessments could be made with greater precision. The compilation of an open, common database with unified information and models would significantly improve the assessment of the carbon impact of electronics and broaden the application of LCA practices for electronic equipment to a wider audience.

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