

# Real Time Waste Classification Using Deep Learning and AV: Deep Learning and Implementation in The Frontend

Akshat Kishore

The Shri Ram School Aravali

## ABSTRACT

To combat climate change, accurate waste disposal is essential at the point of disposal. Strong greenhouse gases like methane are released into the atmosphere when items that might be recycled or composted are instead dumped in landfills. Current efforts to lessen the disposal of incorrect garbage are often costly, incorrect, and long. In this project, we offer NoWa, an intuitive smartphone app that instantly categorises waste into recyclable or compost for consumers. NoWa uses highly efficient deep learning algorithms, using modern deep learning techniques and models. We test several convolution neural network topologies for garbage detection and classification. On the test set, our best model, a multi-layer deep learning residual convoluted neural network, has an accuracy of more than 95%- a number higher than what has ever been achieved in such models.

## Introduction

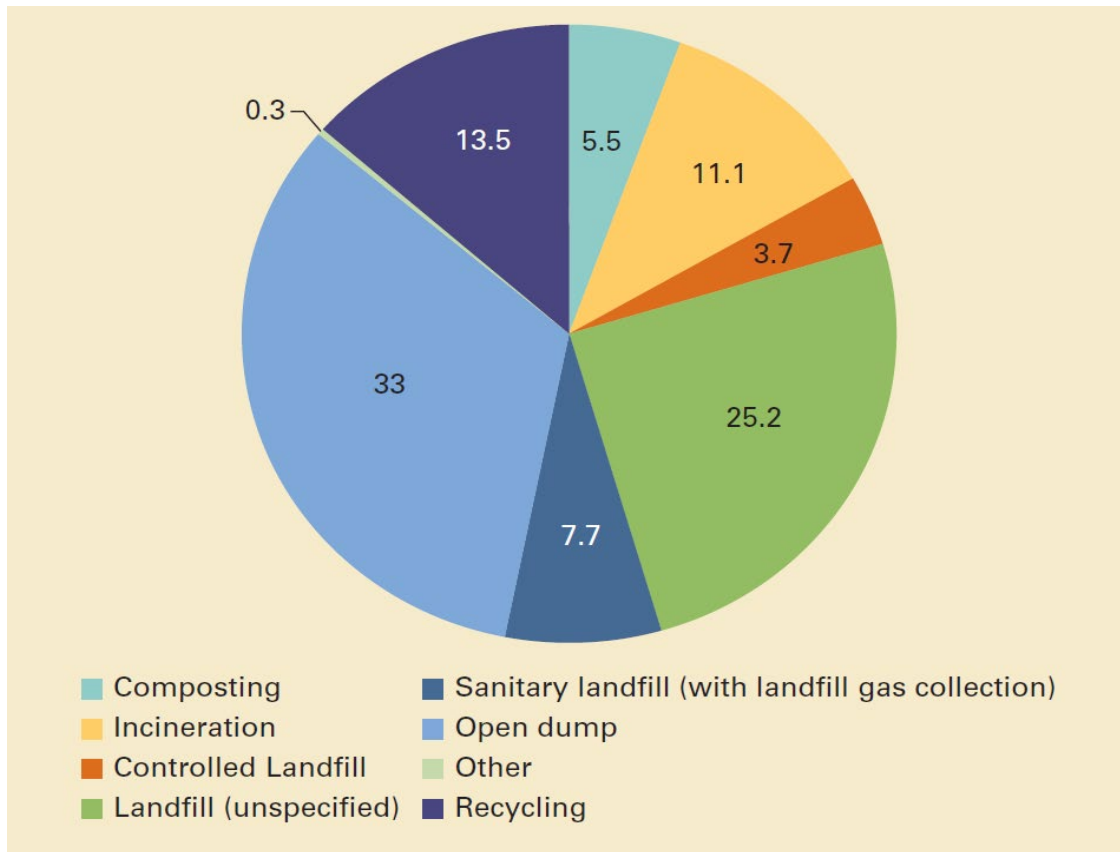
The world produces more than 2 billion tonnes of solid trash annually. Even though most of this garbage can be recycled, only 20% of it is recycled in the India [1]. Additionally, only around 6% of food and other organic waste gets composted in India, and only 9% of plastic is recycled globally [2] [3]. According to World Bank data, Solid waste-related emissions are anticipated to increase to 2.38 billion tonnes of CO<sub>2</sub>-equivalent per year by 2050 if no improvements are made in the sector [4].

Despite significant financial commitment, attempts to inform the public about proper trash disposal have so far had only fair results. What can be recycled or composted frequently causes confusion in people. Waste containers are frequently surrounded with signs and boards that are hard to see and frequently leave important information out. Furthermore, trash disposal regulations are susceptible to change on a county-by-county basis since it depends on the capacity of the nearby recycling facilities.

Waste management mistakes result in not only lost possibilities for recycling and composting but can contaminate recycling and compost containers. A single mistake that causes contamination frequently results in an entire bin ending up at a landfill. According to data from the National Garbage and Recycling Association, human error in the proper identification and placement of waste into our waste bins causes contamination of over 25% of recyclables, diverting recyclable materials into our landfill [5]. Recycling or compostable waste that is disposed off in a landfill emits methane, a greenhouse gas that is many times more powerful than carbon dioxide in causing global warming. It is evident through the above data that the methods used to spread awareness in the public currently are not very effective.

In this project, we take advantage of the recent advancements in deep learning (CNNs) for image-recognition tasks and the availability of increased computational power on contemporary cell phones to provide a novel method for waste identification that is quick, affordable, and precise for anyone, anywhere. We introduce NoWa, a one-of-its kind smartphone application that uses deep learning to solve the issue of incorrect

garbage disposal at the point of disposal. A fully annotated dataset of more than 22,000 trash items has been used to train this highly accurate model, which has an average accuracy of 0.95 or 95% on the test set.



**Figure 1.** Close to 1/2 of all waste ends up in landfills

## The Problem

This product aims to provide fast classification of input objects as recyclable/non-biodegradable or biodegradable.

Machine learning for waste classification is difficult for three reasons.

1. First, a waste's ability to be recycled or composted depends on the material's characteristics, which can be challenging to determine from an image alone.
2. Second, any machine learning technique must account for the fact that the material may be in any shape, such as a shattered bottle, a crumpled can, or distorted plastic.
3. Third, the ability of the local recycling facility to process a certain material determines whether it can be recycled, so the app must take this geographic factor into consideration. To complete the required objective, a dataset of more than 20,000 images was obtained and processed using Python and Jupyter Notebooks IDE.

We read a series of peer-authored research papers on image classification, researches from renowned universities and various articles on the internet. We used the newly acquired knowledge to start brainstorming, data exploration and finally, building the model.

## Ethics and Features

We have aimed to incorporate Microsoft's Responsible AI and Ethics Code in our product, NoWa, as below:

1. Inclusivity- We have made sure that NoWa is available on both iOS and Android platforms, available to be downloaded by almost any user across the globe.
2. Fairness- Our product aims to provide an easy-to-use platform for classification of wastes seen in daily life, giving people access to a tool to help easier segregation of wastes and inversely reduce the waste which ends up in landfills.
3. Privacy- both versions of the app ensure full privacy of the user by using the native permissions feature on both Android and iOS. That is, the app asks for permission whenever camera access is required. The user can select from a range of standard options including "while using app" and "only for once".
4. Reliability and Safety- our machine learning models have been trained on a big dataset and thus has a high accuracy. Thus, the model predicts correct output almost all of the time it runs.

## Research Methods: Code Overview

After a long process of data exploration including analysis of classes through pie charts, frequency through bar graphs etc., the images were passed to a Keras Sequential model with various layers including activation (we used the standard Relu activation, which basically tells the neuron in the neural network to return 0 if the input is negative otherwise return the input as it is), Conv2D (to create neural network to produce a series of output tensors), and a MaxPooling Layer (which breaks the image into rectangular samples and computes the maximum in each of these regions). These were added as layers to the Sequential model.

The code for the model included creating a train and test generator to make the model run faster and be more optimised for mobile devices.

Then, the model was saved as a .tflite file and integrated into the Android Studio and Xcode Environments (as a standard file and as a part of the interpreter respectively). In Xcode, we took it another step to incorporate real time object detection using the AV Classes.

## Python Model

### Libraries

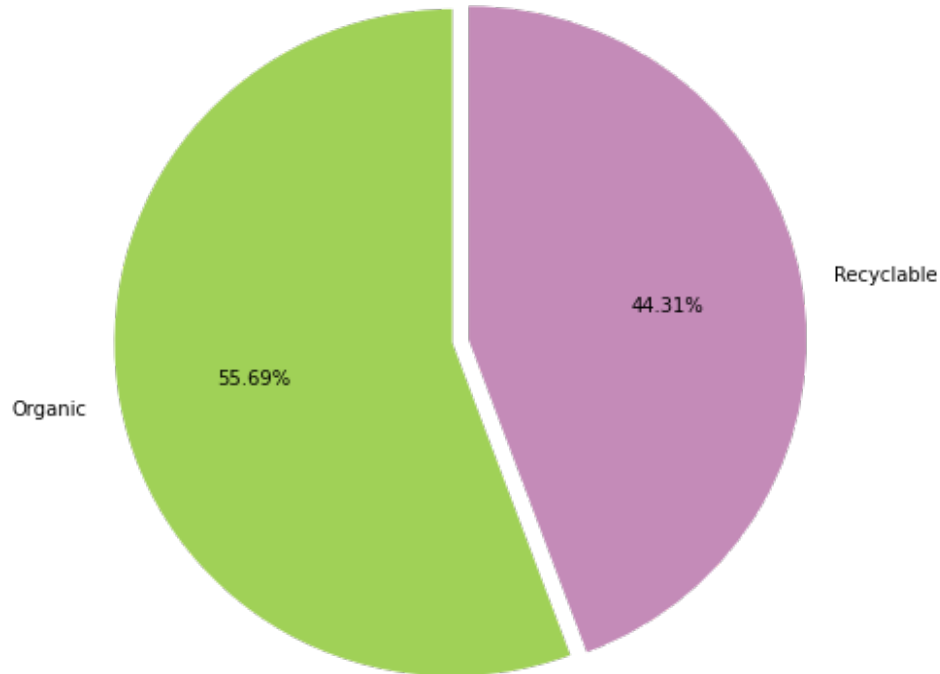
We used a range of Python libraries to implement our model. These included the following: Numpy, Pandas, Matplotlib, tqdm and cv2.

Deep learning libraries include the tensorflow Keras models, layers and pre-processing and utils.

### Data

The dataset has been obtained through the publicly available data on waste classification, procured through the internet and imagenet.

The dataset consists of a total of 25,084 images of Organic and Recyclable objects of all types- from fruits to curtains, almost anything the user may input.



**Figure 2.** Distribution of classes and data

## The Model

We used a Keras Sequential model to create the neural network. The model creates a standard neural network with a stack of multiple layers added for optimisation and accuracy. These layers were specified explicitly in code and are visible in the figure below. The parameters of each layer were fine tuned to optimise the model and increase its accuracy. Optimisation was particularly important in this case since the model would eventually be deployed to mobile devices and provide classification in real-time.

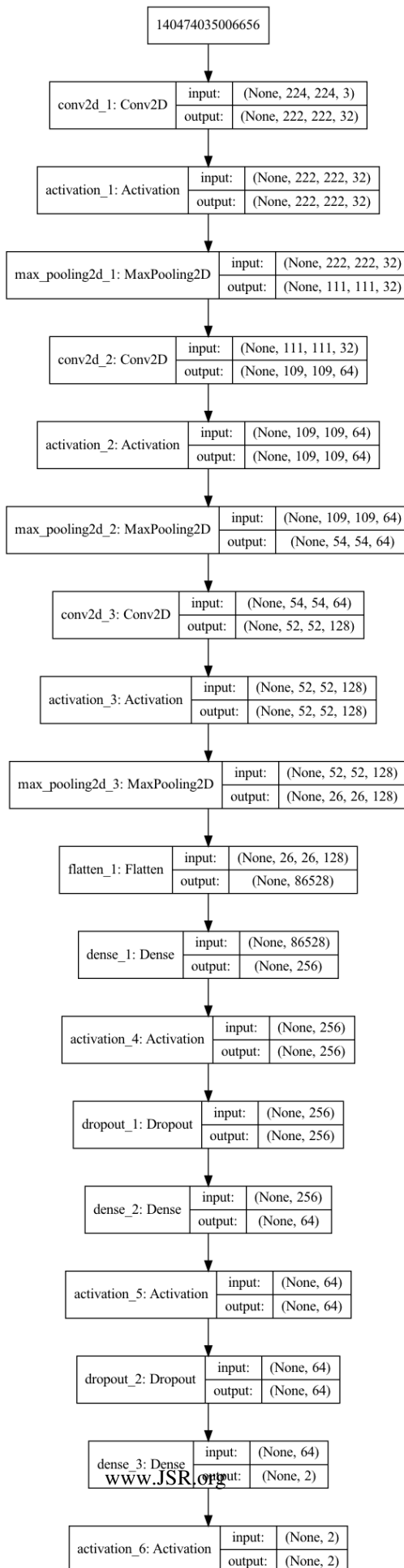
Some of these layers include MaxPooling layers to downsample, Relu activation layers (again, Relu is computationally optimum), and Dense and Flatten layers.

This is due to the following reasons:

1. The model requires one input image, which will be passed by the user of the mobile application.
2. The model predicts one output, which is the classification of the waste.
3. There is no branching within the model- it gives a single output.

The entire model, with description of each layer, its properties, and the added methods are depicted visually in the figure above.

The model uses a number of layers to create a deep learning network with maximum accuracy. Several optimisation layers are also included to increase the efficiency of the model, permitting it to run on mobile applications.



## The Frontend: Creating an IOS App Based Using Custom AI Models

### Deploying the Model

The model created in the previous section was saved as a light, portable. tflite file. This format is useful for optimisation and deployment on mobile devices. The TFLite file is meant to behave the exact same way as the model, and takes the same inputs and results in the same outputs. This file format increases the speed of the app since a round trip to the server is prevented.

### Interpreter

The first step to develop the front end is to set up the interpreter. To do this, we simply created an Interpreter object, initialised with the TFLite model created above. Before this, the TensorFlowLite library was added to the pod file of the project.

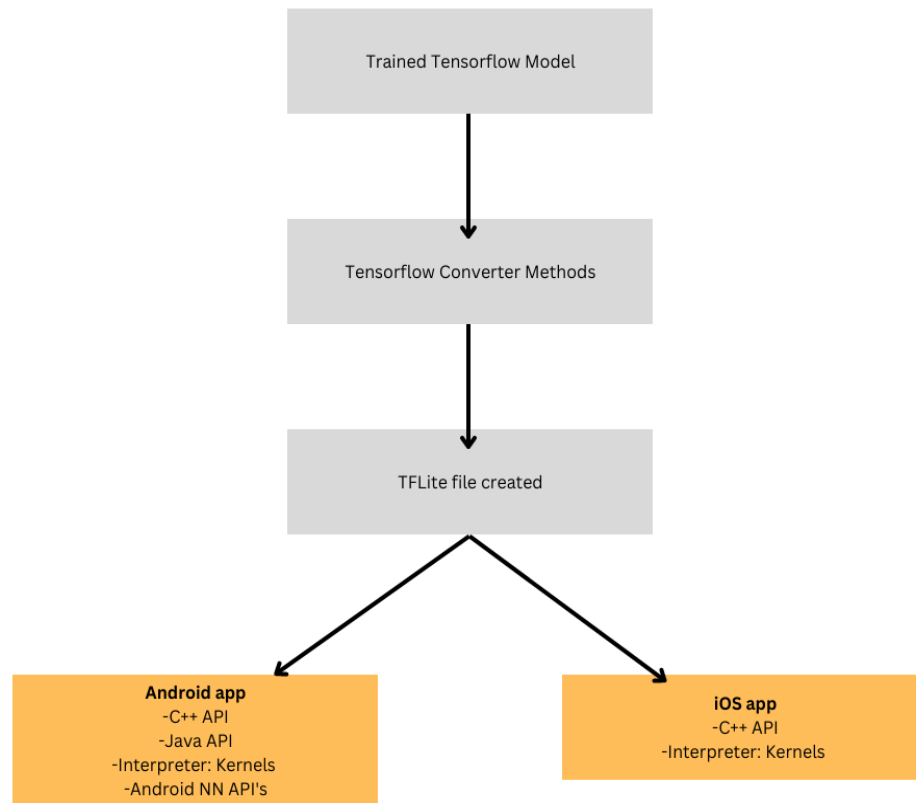


Figure 4. TFLite files

## Real Time Input: AV Classes

The AV classes were used to process the input for real time object detection. The figure below shows the flow of AV Classes for obtaining input for our model.

The base for getting the input was the `AVCaptureSession` class. As input to this was passed the `AVCaptureDeviceInput` object. The `AVCaptureVideoDataOutput` was used to process the obtained frames from the obtained video.

To display the contents of the camera to the viewer, the `AVCaptureVideoPreviewLayer` class was used and initialised under the `previewView`.

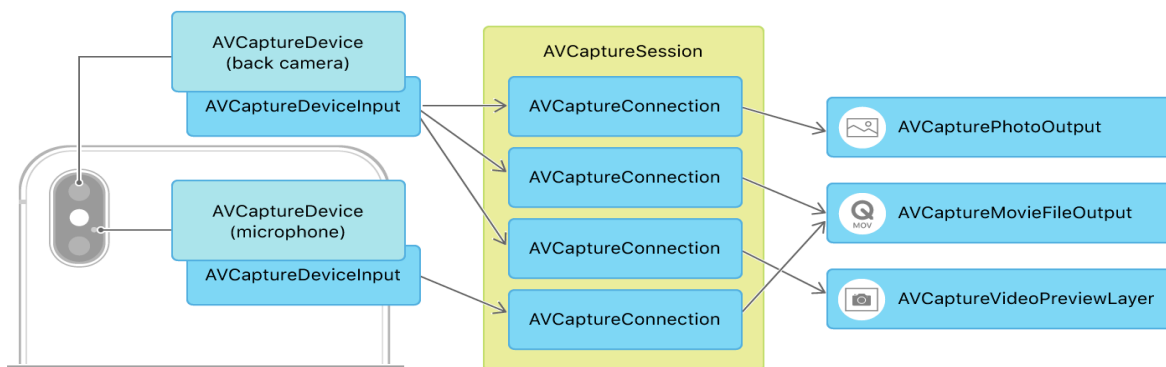


Figure 5. AV Classes flow. Taken from Apple Developer Documents

## Running the Model

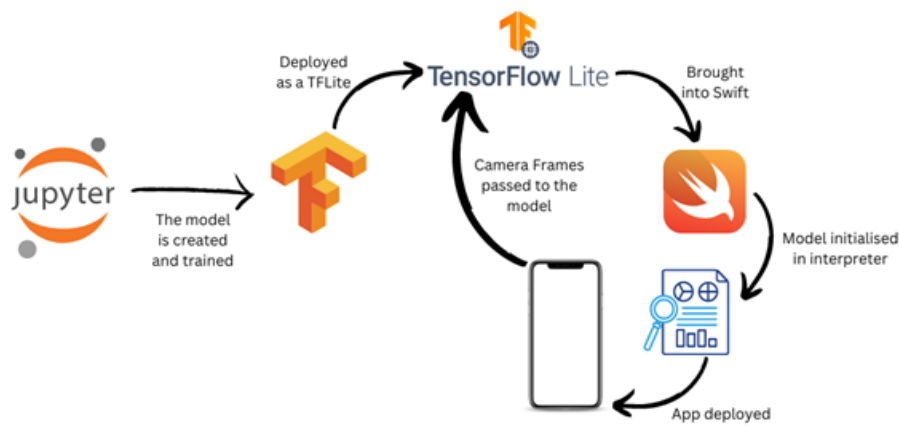
The model is available in the form of a TFLite file.

1. We pass a `CVPixelBuffer` created from each frame of the `AVCaptureVideoDataOutput` to run the model. The pixel buffer is of type `32RGBA`, `32BGRA` or `32ARGB`
2. The obtained buffer is scaled to `224*224` which is the input shape of the model we created in Python and extract a buffer of this size from the centre of the original buffer.
3. This scaled buffer is then converted to RGB data.
4. At this point, we invoke the interpreter- note that the interpreter has been initialised to our model, so the interpreter output is nothing but the output of the model.
5. We store this as a Tensor, which is then quantised to a `UInt` or `Float32` based on the datatype present in the Tensor.

The figure above shows a graphical representation of the entire process described.

## User End Product

The entire product can be summarized as described in the figure.

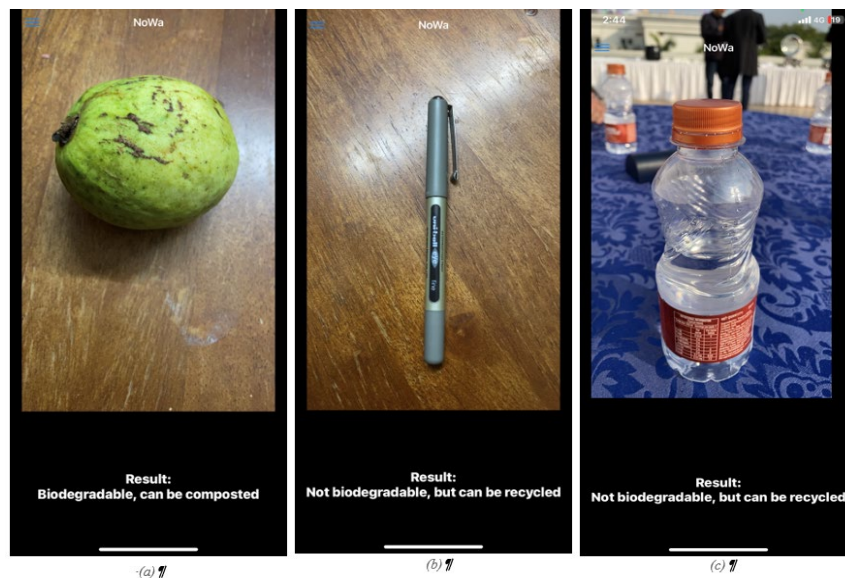


**Figure 7.** Workflow of creating the NoWa app

## Results

The figure below depicts the NoWa app categorising frequently misunderstood items in actual life. Any bit of trash can be scanned with a smartphone, and the user will instantly receive feedback with an average forecast time of about 2-4 seconds. Even when the shape has been altered, NoWa can accurately recognise objects like crushed soda cans, orange peels, apple cores, crumpled paper, and plastic bags and a lot more.

The NoWa app provides classification in a time frame of 2-5 seconds depending on the build of the phone. Thus, the model is able to give results in a short time frame, without any required internet connection. That is, the app can be used fully even in the absence of an active internet connection. As shown below, the NoWa app can effectively and swiftly classify real life objects in real life scenarios.



**Figure 8.** Working of the NoWa app in real-time



## Conclusion and Future Work

In this paper, we suggest a mobile app that use highly efficient deep learning techniques to give users rapid waste classification, enabling them to correctly dispose of garbage into recycling, compost, or trash. The mobile app is currently accessible to beta users for testing. We plan to build a bigger data set in the near future by making the app available to everyone so that more people can contribute to the expanding NoWa database. In order to determine whether they would be interested in encouraging their clients to embrace NoWa, we have started a conversation with a few nearby recycling businesses. The preliminary responses have been positive, and we expect to keep talking about this and launch a study soon. With time, we want to increase public awareness of the negative effects that improper garbage disposal has on the ecosystem and the climate. It will be equivalent to taking off 6.5 million gasoline-powered passenger vehicles from the road, as shown by NoWa, which shows the potential for machine learning techniques to address difficult climate change-related problems.

## Acknowledgments

I would like to thank my advisor for the valuable insight provided to me on this topic.

## References

- [1] <https://timesofindia.indiatimes.com/blogs/voices/recycling-waste-can-generate-crores-in-revenue-in-india/>
- [2] <https://www.nrdc.org/stories/composting-101>
- [3] <https://www.cseindia.org/plastic-waste-is-india-s-and-the-world-s-most-formidable-environmental-challenge-10375>
- [4] [https://datatopics.worldbank.org/what-a-waste/trends\\_in\\_solid\\_waste\\_management.html](https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html)
- [5] <https://fivethirtyeight.com/features/the-era-of-easy-recycling-may-be-coming-to-an-end/>