The Plastic Use and Life Cycles: A Systems Approach

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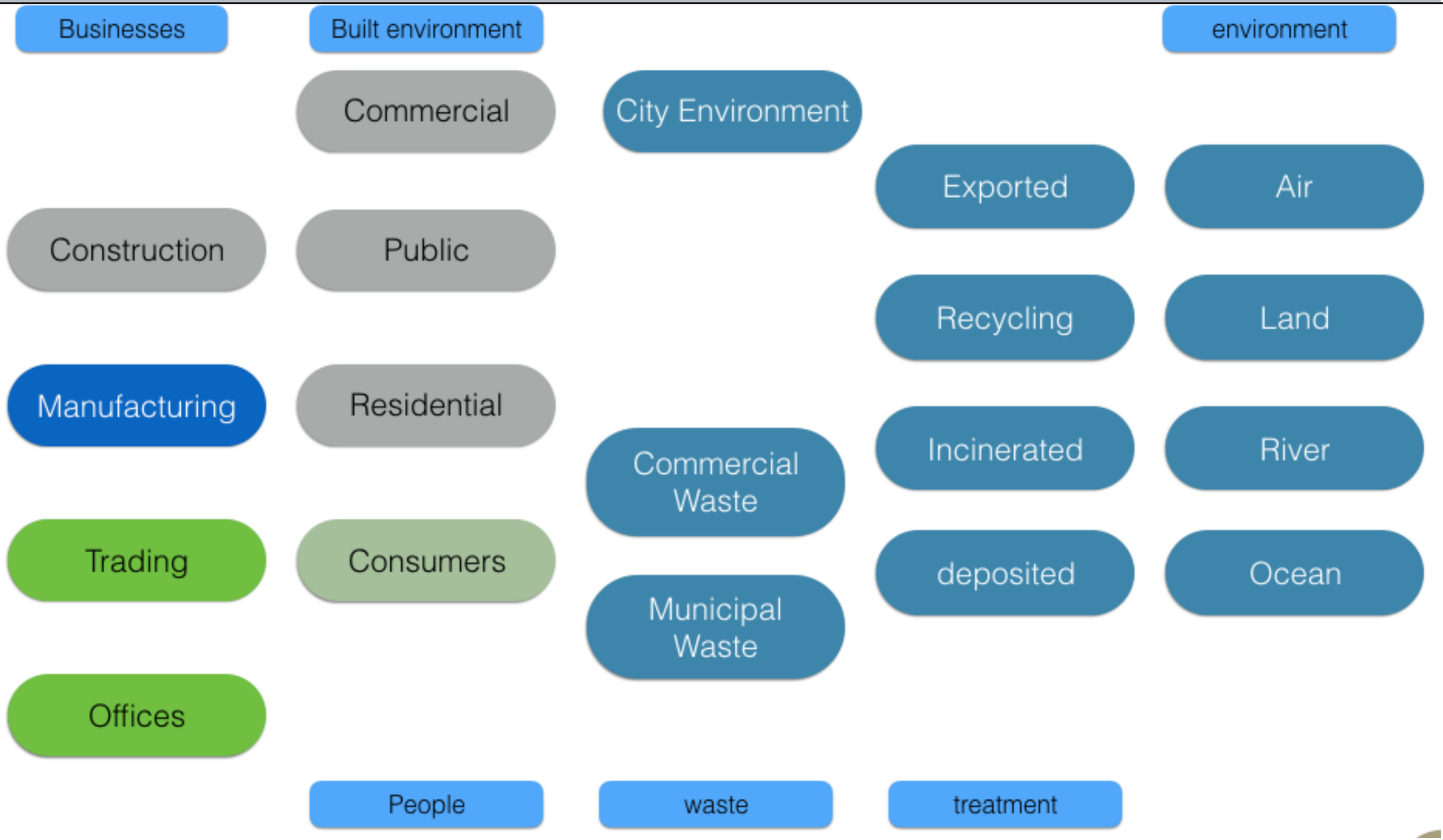
Towards a Conceptual Model



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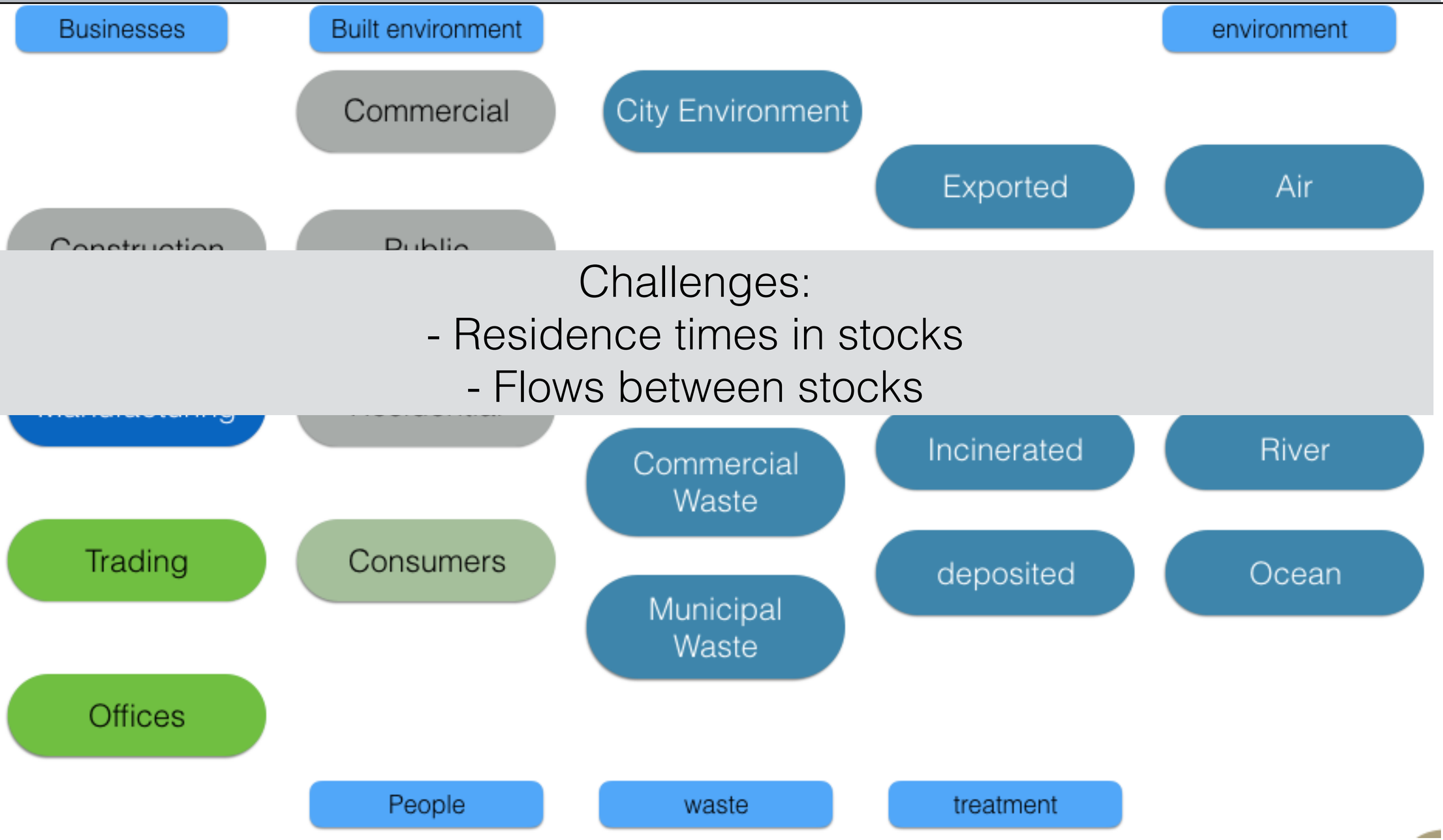

Challenges:
- Residence times in stocks
- Flows between stocks

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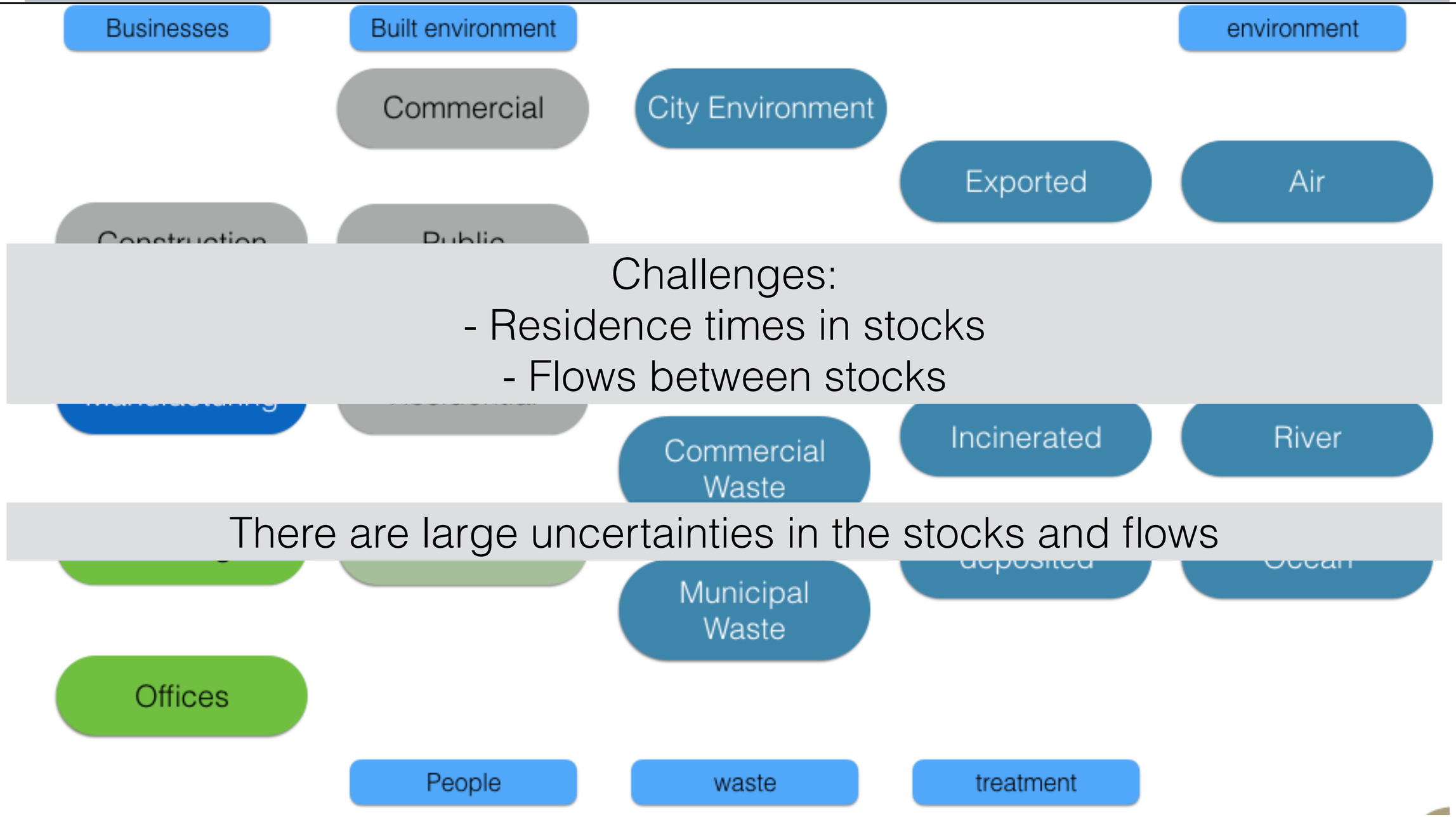


Challenges:
- Residence times in stocks
- Flows between stocks

There are large uncertainties in the stocks and flows

Towards a Conceptual Model

SFM for Plastics

Scale (for society):

- Household: *important for agent-based model*
- Business: *important for agent-based model;*
- Municipality: *can impose regulations for businesses and customers; determines fees and taxes*
- State: *can impose regulations for businesses and customers; determines fees and taxes*
- Country: *can impose regulations; trade regulations, taxes, etc.*
- Globe: *international and intergovernmental trade regulations*

System of systems model with different SFMs for different scales and systems for the whole of society

Scale-dependent models:

- Business: *those directly impacting plastic production, use, recycling, disposal, and trade*
- Municipality: *can include production, use, disposal/recycling of plastics*
- State: *composed of several municipalities*; *can include state-level production, disposal/recycling of plastics; exchange with other states;*
- Country: *composed of several states; trade with other countries;*
- Globe: *composed of many countries*

Towards a Conceptual Model

SFM for Plastics

Scale (for environment):

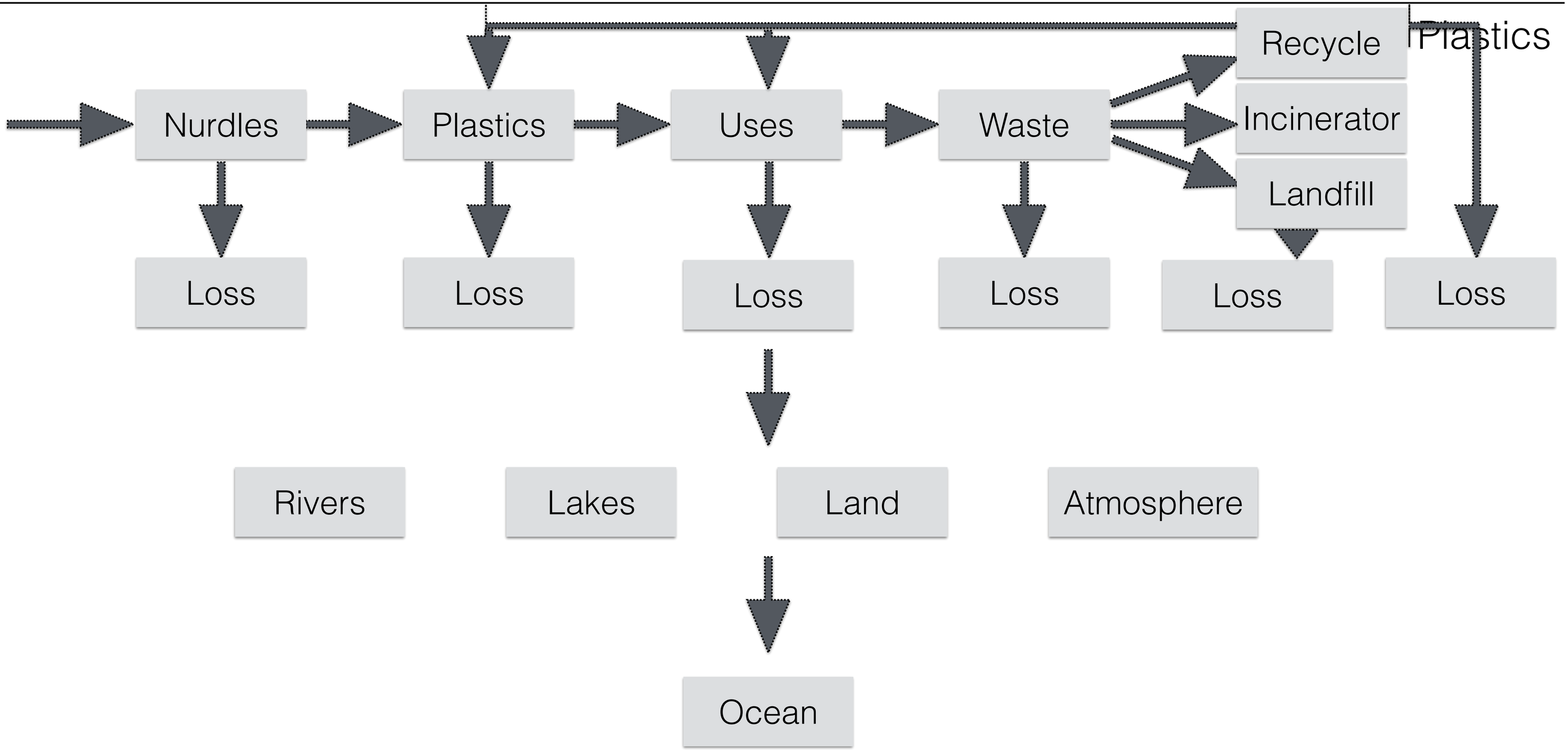
- rivers (watershed);
- lakes;
- land (watershed);
- atmosphere
- ocean

System of systems model with different SFMs for different entities for the whole of the environment

Scale-dependent models:

- watershed (land, river, lakes)
- atmosphere
- ocean

Towards a Conceptual Model



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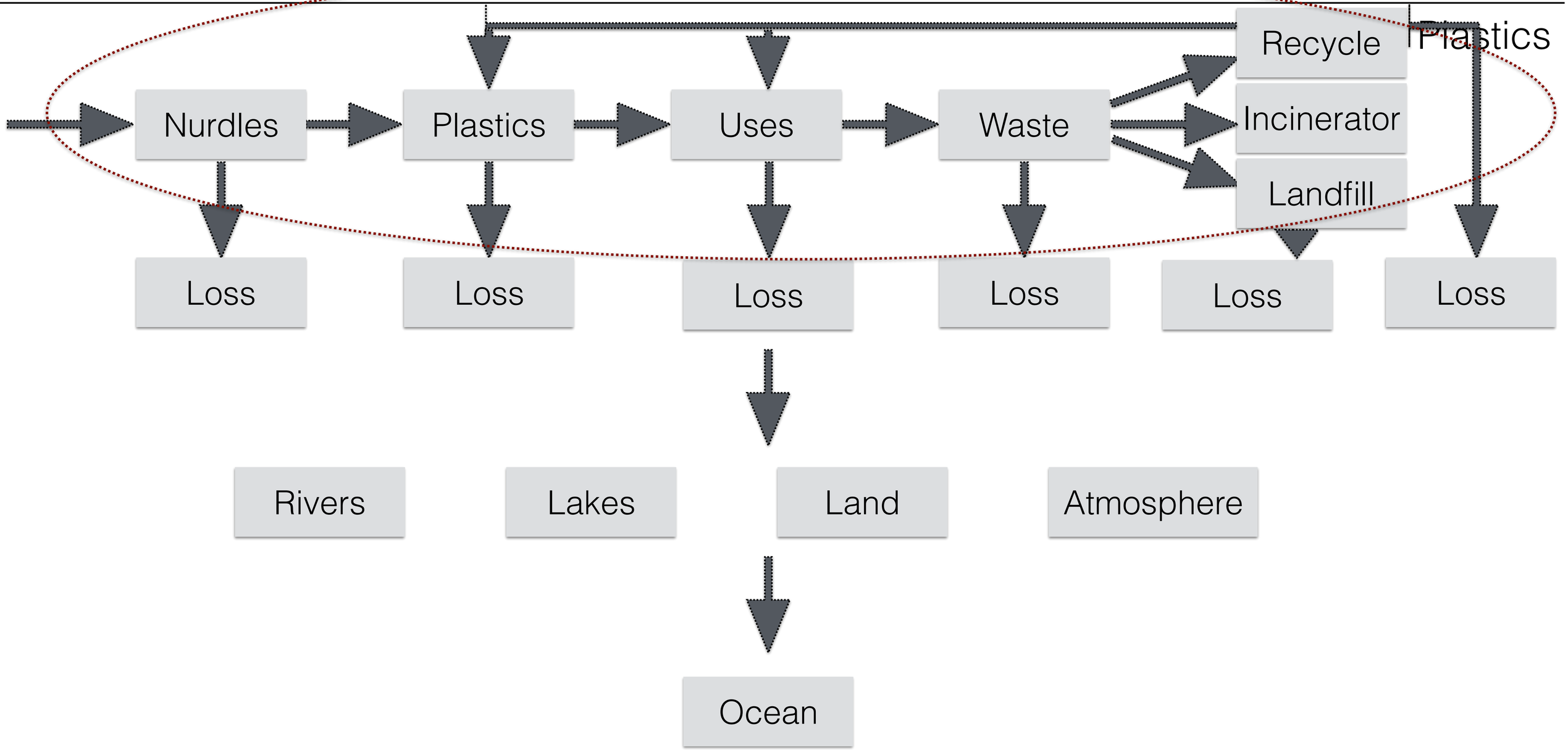

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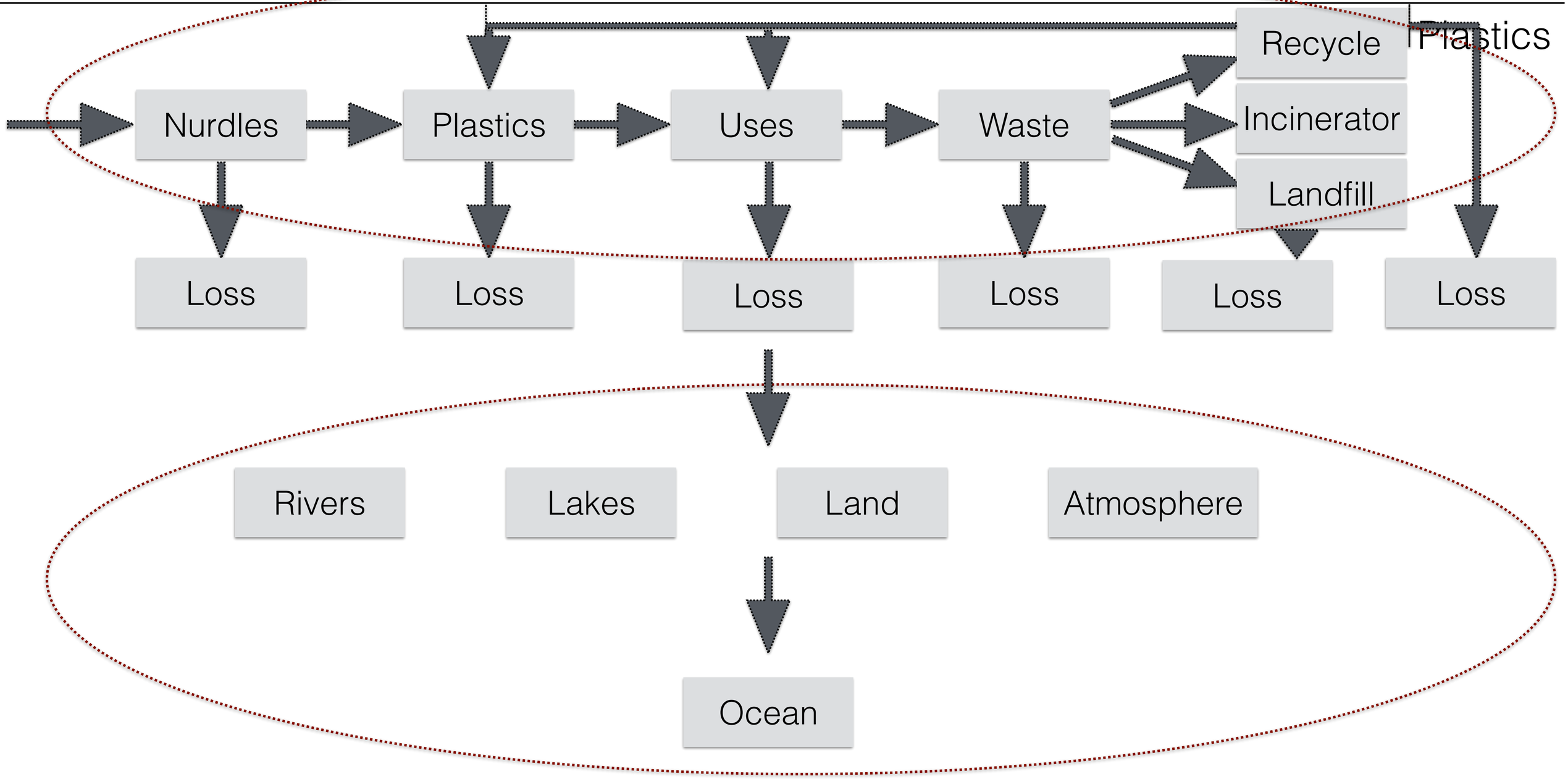

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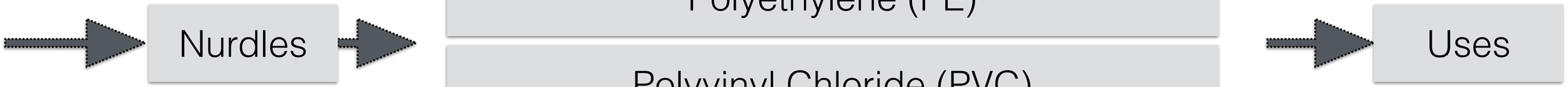
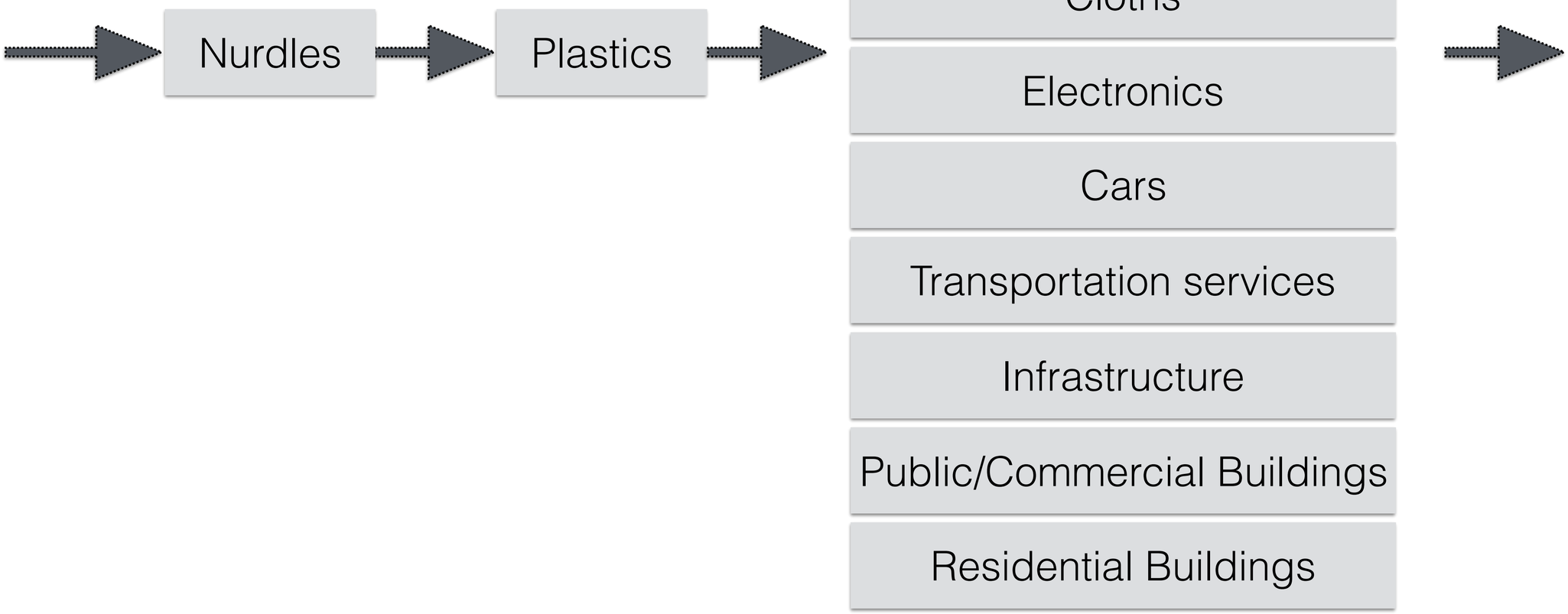
SFM for Plastics



- Polyethylene terephthalate (PETE or PET)
- Polyethylene (PE)
- Polyvinyl Chloride (PVC)
- Polypropylene (PP)
- Polystyrene (PS)
- Polylactic Acid (PLA)
- Polycarbonate (PC)
- Acrylic (PMMA
- Acetal (Polyoxymethylene, POM)
- Nylon (PA)
- Acrylonitrile Butadiene Styrene (ABS)

Towards a Conceptual Model

SFM for Plastics



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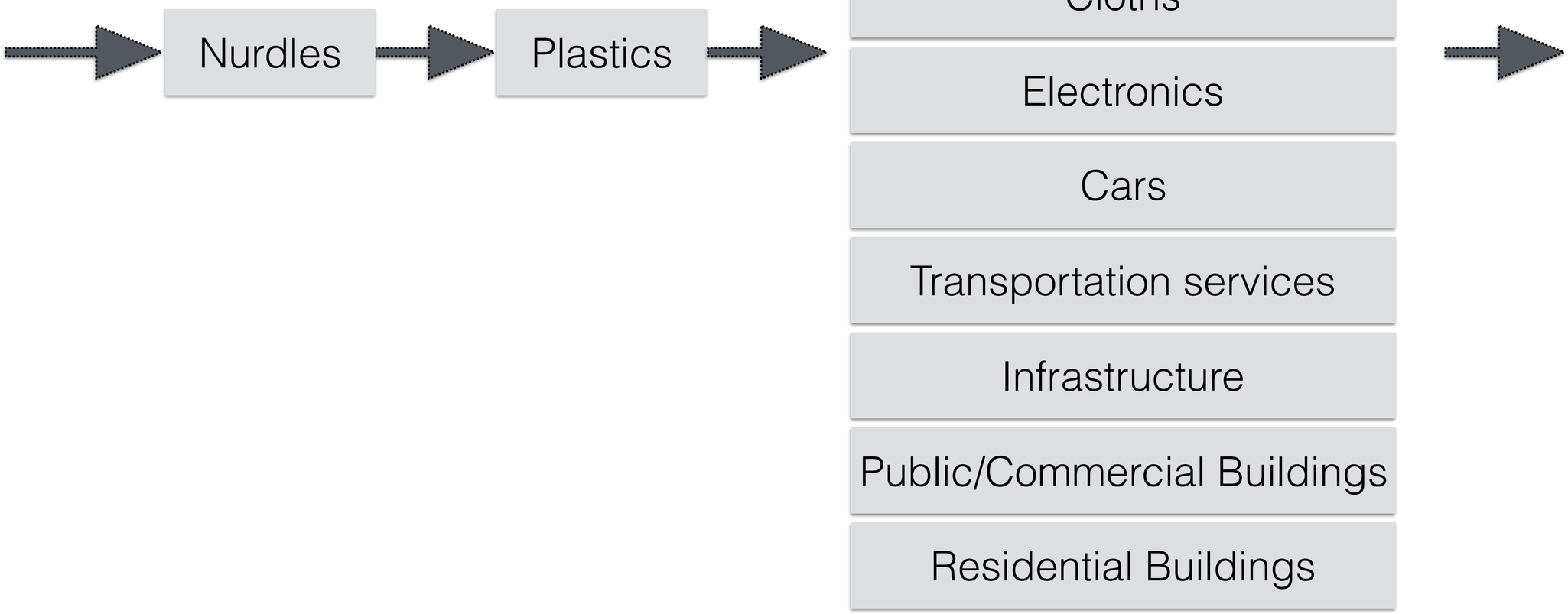
SFM for Plastics



Stock and Flow Model

Stocks depend on the flows in and out of a stock

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In general, in each time step (each year), stocks are changed by adding the flows into the stock and subtracting the flows out of the stock:

$$ {}_{i}S_{\text{acronym}} = {}_{i-1}S_{\text{acronym}} + \sum_{j=1}^{J} {}_{i}F^{\text{acronym}}_{\text{acronym}_\text{j}} - \sum_{k=1}^{K} {}_{i}F^{\text{acronym}_\text{k}}_{\text{acronym}} \tag{4} $$

where J and K are the numbers of stock-specfic flows into and out of the stock, respectively.

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Flows out of a stock depend on residence time

The flows out of a stock depend in general on the residence time of the items in a stock. The residence time is not the same for all items, and residence times can be given as a residence time distribution which specifies the percentage of items that have a residence time of n time steps for $n = 1, ..., N$.

$$ R(n) = p_n \ , \ n = 1, N, \tag{5} $$

where N if the maximum residence time in time steps. A flow F out of stock S at time step i can then be computed as

$$ {}_iF_{\text{acronym}} = \sum_{j=1}^{N} {}_{i-j}F^{\text{acronym}} \cdot R(j) \ , \tag{6} $$

where “acronym” is the acronym for stock S.

Stock and Flow Model

Flows can be demand-drive or supply-driven

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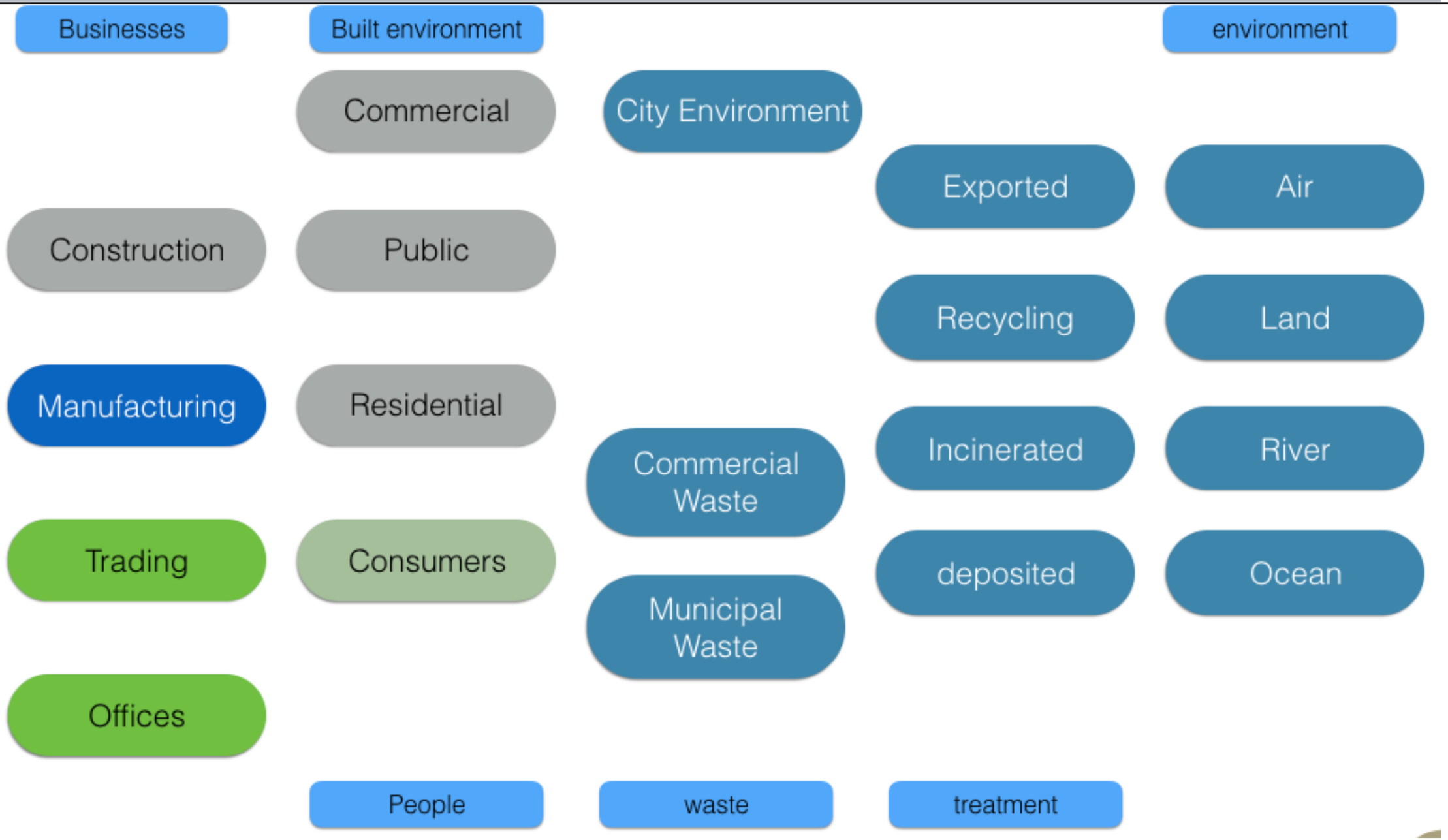
Construction (cons): The flow into the stock S_{cons} is an on-demand flow and equals the flow out of this stock. The flows out are depending on the buildings being constructed in a given time step, the amount of plastic needed per unit of buidings, and on the fraction of plastic turned into waste during construction. The flow ${}_iF^{\text{cons}}$ is given by

$$ {}_iF^{\text{cons}} = (1 + r_w) \cdot ({}_{i-1}F^{\text{comm}}_{\text{cons}} + {}_{i-1}F^{\text{publ}}_{\text{cons}} + {}_{i-1}F^{\text{resi}}_{\text{cons}}) \,, \tag{7} $$

where r_w denotes the fraction of plastic that is turned into waste during construction. Here, the assumption is that in any given time step, the plastic added to S_{cons} is equal to what was used in the previous time step.

Stock and Flow Model



Stock and Flow Model