Transition Towards Circular Economy

-Secondary Material Flows in the Finnish Economy

WP 2

Annika Johansson, Henri Virkkunen

Centre for Sustainable Consumption and Production

Finnish Environment Institute

ENVECO webinar, 25.1.2021

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Linear Economy VS Circular Economy
An ongoing transition

- **Growth in global population and rise in the standard of living**
  - Result in increased demand on on natural resources and environmental impacts
  - Full reliance on imported, virgin–materials may prove problematic in crisis situations

- **Prevailing linear economy:**
  - High reliance on virgin materials, many of which are non-renewable or in the long term unsustainable to extract
  - Significant material flows are inefficiently recycled and re-use rates remain low

Linear Economy VS Circular Economy
An ongoing transition

- **Global population growth increases the demand for natural resource extraction**
  - Resulting in increased resource drain and environmental impact
  - Full reliance on imported, virgin materials may prove problematic in crisis situations
- **Traditional, linear economy:**
  - High reliance on virgin materials, many of which are imports, non-renewable and unsustainable to extract
  - Relatively inefficient recycling and re-use of most types of waste
  - Significant material flows remain outside of recycling and re-use

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Linear Economy VS Circular Economy
An ongoing transition

- **The key ideas of Circular Economy:**
  - Reduces the consumption of virgin materials
  - Focuses on the reuse and recycling of materials already in circulation (secondary materials)

- **The benefits of Circular Economy:**
  - Reduces extraction pressure on natural resources (primary raw materials)
  - Reduces environmental impacts including greenhouse gas emissions from resource extraction

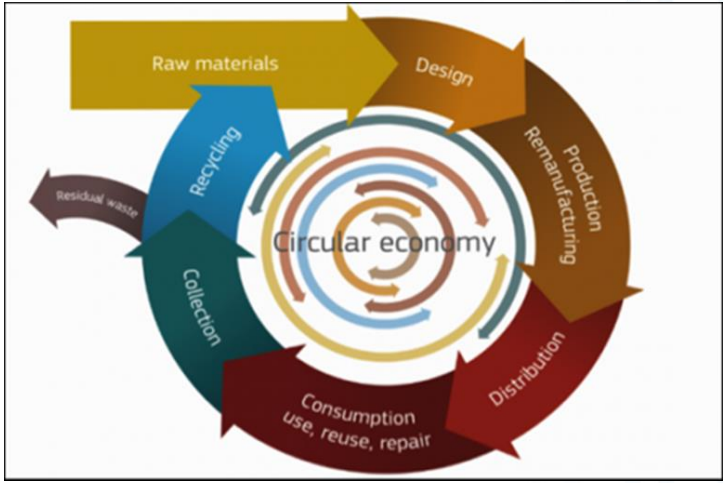

Image source: https://ec.europa.eu/easme/en/news/r2-supporting-transition-circular-economy

- For an efficient Circular Economy, comprehensive collection, recycling and recovery of materials is essential.

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How to Implement the Change to Circular Economy?

- Strong legislative emphasis on a shift from linear to circular economic structure. e.g.
  - EU Waste Framework Directive 2008/98/EC & Amendment 2018/851
  - Circular Economy Action Plan, 2020

- Waste Framework Directive sets ambitious recycling targets for:
  - Packaging: 85% paper & cardboard, 80% ferrous metals, 60% aluminum, 75% glass, 55% plastics and 30% wood by 2030-2035
  - Household waste: minimum 55% by weight by 2025
  - Construction waste: 70% by 2020, to be updated at a later stage

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Background to WP2

- Current national waste statistics and material flow accounts do not separate between secondary and primary material flows or address reject in secondary material production
  - The development of secondary materials accounting supports Circular Economy-related planning, monitoring and policy-making, targeting of activities which facilitate circularity
    - Promotes the assessment of environmental impacts (benefits) and economic impacts, e.g. in environmental extended input-output modeling
  - Difficulties in quantifying or assessing the supply and use of secondary materials makes it hard to monitor the progress of the transition

- Secondary material accounts describe the flow of secondary materials within the Finnish economy
  - Production volume of secondary materials
  - Amount of wastes/side products used in their preparation

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Goals of WP2

- Improve the monitoring of the transition to circular economy in Finland and EU
  - We assessed the availability, representativeness and quality of data available for secondary material accounts
  - We recognized data gaps and possible future development areas
  - We made the share of different industries in the generation and processing of secondary materials visible

- To this end, we provide an accounting-based methodology for creating material-specific flow accounts on secondary materials
  - We dollected data from several sources were combined and assessed together, in order to create a comprehensive picture of material flows within the Finnish economy

  The accounts…
  - separate specific industries and assessed their contribution to an individual material flow
  - provide a bird's eye view of the material flows in the entire economy
  - enable the detection of temporal changes in secondary material flows over time
  - are delivered to Statistics Finland to enable visualization of secondary material flows via e.g. Sankey diagrams.

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Workflow for Secondary Material Accounting: Selected Waste Materials

- 14 waste materials selected for examination:
  - Glass
  - Plastic
  - Wood
  - Iron and steel
  - Aluminum
  - Copper
  - Paper
  - Cardboard
  - Concrete
  - Tiles
  - Rubber
  - Sand, gravel, clay and crushed stone
  - Fertilizers
  - Mineral fractions from slag

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Workflow for Secondary Material Accounting: Data Sources

- **Data sources:**
  - Direct information inquiries to enterprises.
    - ca. 70 companies, production units or organizations engaged in waste collection, processing and secondary material production.
  - Producer responsibility statistics
  - Data on the origin, processing and shipments of waste reported in VAHTI/YLVA compliance monitoring system
    - Received waste, treated waste and waste utilized in secondary material manufacturing
    - Includes facilities operating with Regional State Administrative Agency permits (domestic waste or smaller facilities not included)
  - Data on fertilizer manufacturing (Finnish Food Safety Authority)
  - National waste statistics, data from industry organizations
  - Import-export data: Finnish Customs database
  - Database on estimated composition of MSW (Municipal Solid Waste) by Suomen Kiertovoima ry
  - Public sales information on companies (Suomen Asiakastieto Oy)
  - Data on building demolition (Building and Dwelling Registry) + estimates on waste produced in demolition (Ytekki Oy)
  - Slag from waste incineration: data by Official Statistics Finland
  - Data on the use of sand, gravel, clay and crushed stone (Confederation of Finnish Construction Industries RT)

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Workflow for Secondary Material Accounting: Data Collection

- Data were collected for all stages of the waste cycle, where available:
  - Generated (primary) waste
  - Waste collected, processed and delivered to secondary material producers
  - Waste received by secondary material manufacturers
  - End-product: amount of produced secondary materials
  - Material reject and loss
  - Import/export
  - Landfilling and incineration

- However, large gaps in data on landfilling and incineration, as focus on data collection was on secondary materials
- Industry sector disaggregation was added to the data, following a 26-industry scheme utilized in the environmentally-extended input-output model ENVIMAT
  - More detailed industry subdivision also possible, up to ca. 150 classes, but a compromise is needed as data availability and quality is a restriction!

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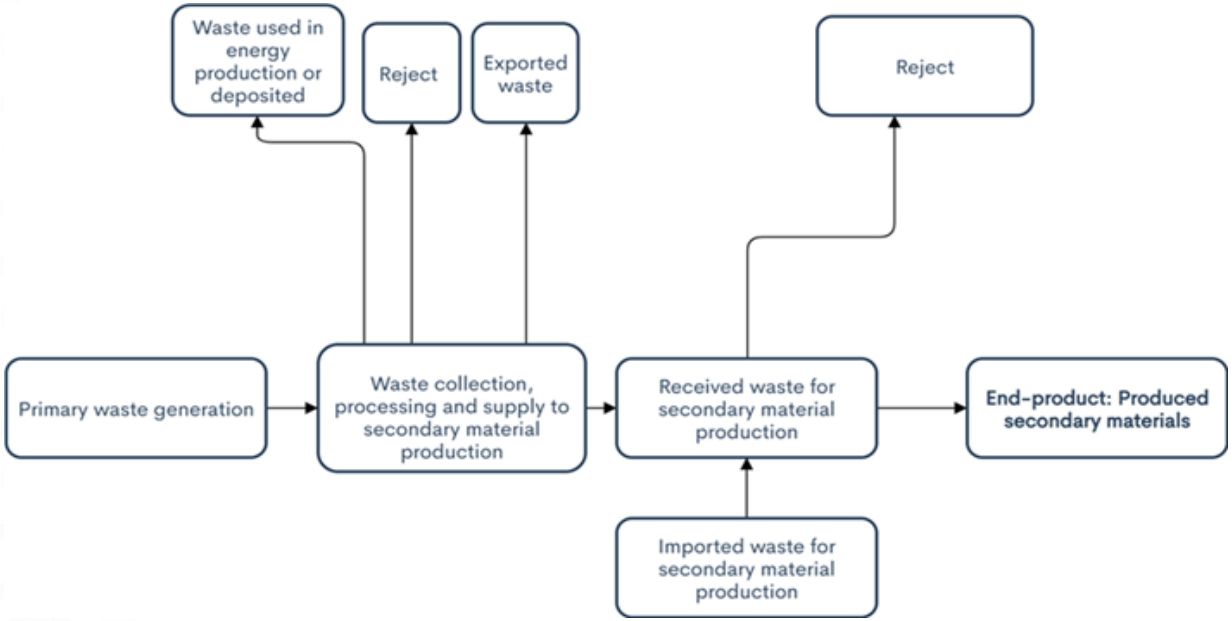
Workflow for Secondary Material Accounting: Data Collection



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Workflow for Secondary Material Accounting: End-Products and Their Uses

- Overall material flow estimates created for all examined materials:
  - Supply
  - Use, losses
  - Production
  - Gaps and inaccuracies of source data result in varying accuracy between waste types
- These estimates can be made more specific by utilizing the industry subdivision associated with the data, resulting in complete supply and use tables for the desired secondary materials
- For this work, tables are provided for glass waste for demonstration

Figure 4. The summary supply table for paper and cardboard waste in 2015 and 2018 in Finland.

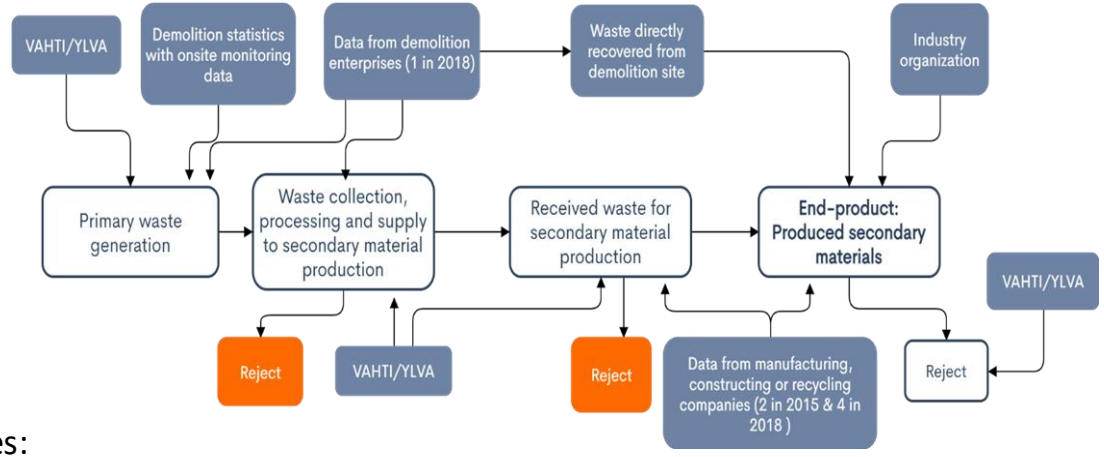
Material	Domestic supply, t*	Import, t
Paper (2015)	367,187	37,130
Paper (2018)	277,803	82,586
Cardboard (2015)	265,121	23,346
Cardboard (2018)	273,833	25,500

* collected paper and cardboard waste

Figure 5.The use and production of secondary materials from paper and cardboard waste in 2015 and 2018 in Finland.

Material	Export, t	Energy production, t	Raw materials for secondary material manufacturing, t*	Reject and loss from secondary material manufacturing, t	Produced secondary material, t
Paper (2015)	54,392	89,964	312,075	69,527	242,548
Paper (2018)	34,335	89,392	313,717	69,685	244,033
Cardboard (2015)	37,798	116,597	269,786	26,979	242,807
Cardboard	34,335	132,767	322,511	64,703	257,819

Data Sources & Uncertainties: Concrete and Brick Waste



- Uncertainties:
  - Inaccurate information on building material composition in demolition statistics
  - Mixed C&DW: actual composition mostly unknown, hard to disaggregate
  - Mixtures of concrete and bricks commonly reported in VAHTI/YLVA, actual composition unknown
  - Manual disaggregation of Concrete and bricks waste class required, work intensive
    - Can possibly be remedied with machine learning methods?
  - Difficult to access data on the amount of waste treated directly on demolition sites, data not systematically summarized by companies and low response rate to company surveys
  - Reject at other phases of the waste cycle besides end product could not be assessed, no data

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Results: Concrete and Brick Waste

Figure 2. Merged summary use and supply table for concrete and brick waste in 2015 and 2018 in Finland.

Material	Supply of waste	Use in secondary material manufacturing, t*	Reject and loss from secondary material manufacturing, t	Supply of secondary material, t
Concrete (2015)		1 633,524	23,274	1 708,431
Concrete (2018)		1 421,773	80,146	1 421,773
Bricks from clay (2015)		104,268	1,795	109,049
Bricks from clay (2018)		157,975	2,178	157,975

* Includes waste received for industrial manufacturing of secondary materials and waste treated directly at demolition sites.

- Concrete and brick mixtures were disaggregated manually by using enterprise-provided ratios
  - 90% concrete and 10% brick from demolition.
  - From other sources, the share of brick was 6%.
- Inaccurate, since the ratios may vary from case to case
- The difference between the figures in *use in secondary material manufacturing* and *supply of secondary material* are due to storage
- The reject concerns contaminated material from VAHTI/YLVA

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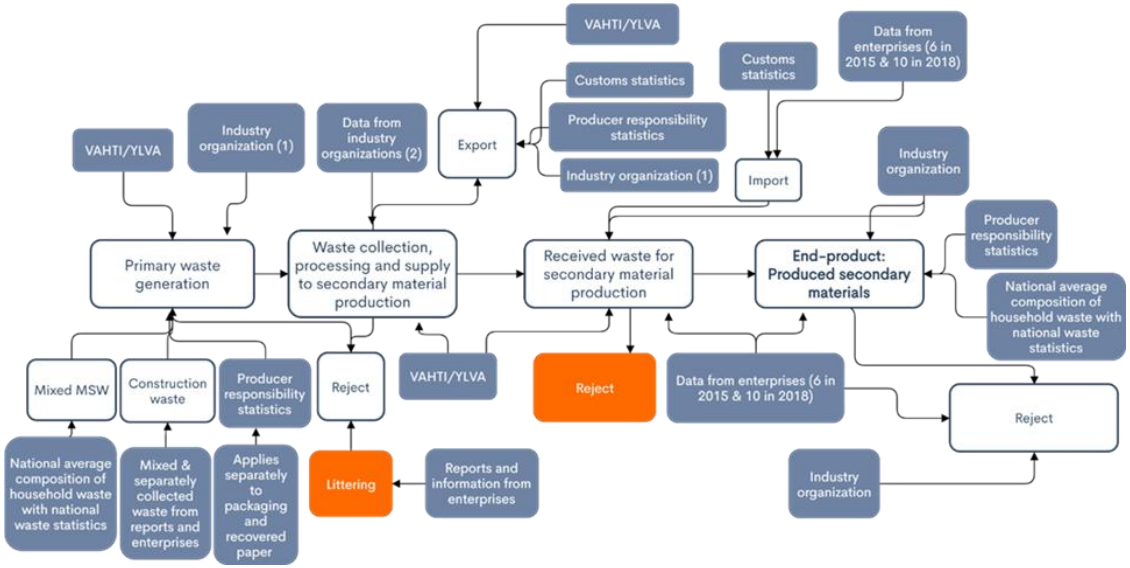
Data Sources & Uncertainties: Paper and Cardboard



- Uncertainties:
  - Data on municipal waste generated were not available because many waste producers (residents, workers, etc.) do not report waste volumes in the VAHTI/YLVA database
  - Data on the packaging material flow resulting from online retail were unavailable
  - The amount of paper and cardboard waste in litter and in e.g. small-scale household combustion were impossible to determine
  - Small waste shipments inside EU that do not require a customs declaration or other permit are missing from statistics

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Results: Paper and cardboard

Figure 4. The summary supply table for paper and cardboard waste in 2015 and 2018 in Finland.

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Paper (2015)	367,187	37,130
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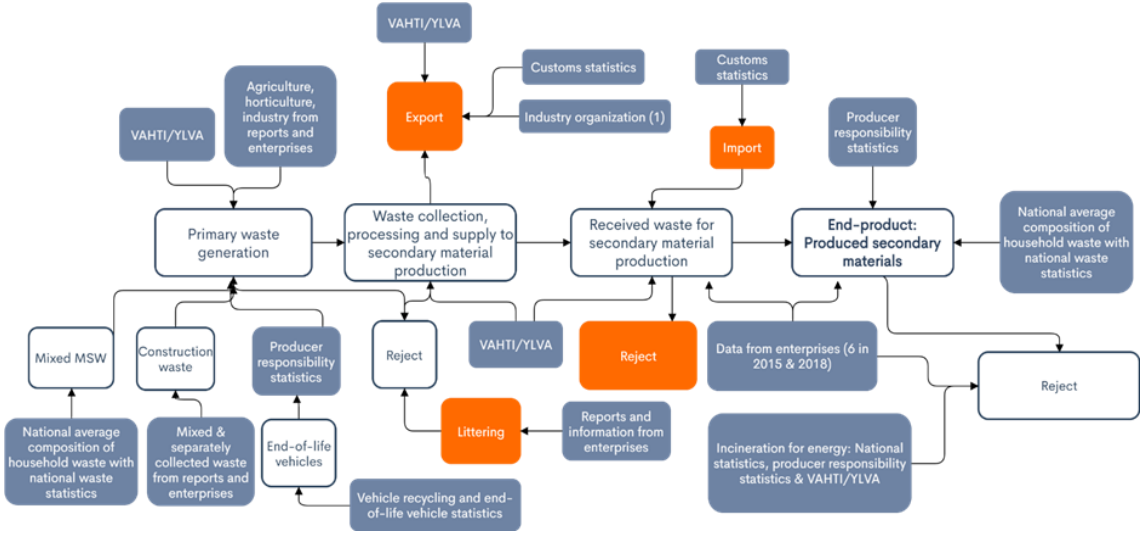
Cardboard	34,335	132,767	322,511	64,703	257,819

- Comprehensive data on paper and cardboard waste streams were obtained, especially towards the ends of the waste cycles
  - Recycling companies responded comprehensively to company inquiries and the response rates were high
    - Companies were well aware of the amounts of waste received, rejects and the amounts of recycled materials produced

The amount of material going to energy production is incomplete and only refers to the amount encountered in this research.

Data Sources & Uncertainties: Plastic Waste



- Uncertainties:
  - Data on municipal waste generated were not available in the VAHTI/YLVA database
  - Data on the packaging material flow resulting from online retail were unavailable
  - Separate collection of plastic packaging from households has only began in Finland after 2015, hence majority of plastic packaging has ended up in the mixed MSW
    - Significant amounts of plastic packaging as well as other plastic waste from households still end up in the mixed waste fractions and incineration (before 2016 also to landfill)
    - Plastic waste has been estimated to be the second largest material fraction of mixed household solid waste and a large proportion of mixed C&D waste
  - Small, unregistered waste shipments are outside of export statistics

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Results: Plastic Waste

Figure 7. The summary supply table for plastic waste in 2015 and 2018 in Finland.

Material	Domestic supply, t*	Import, t
Plastic (2015)	41,791	1,317
Plastic (2018)	42,008	3,859

* collected plastic waste, based on Producer responsibility statistics

Figure 7. The use and production of secondary materials from plastic waste in 2015 and 2018 in Finland.

Material	Export, t	Energy production, t	Raw materials for secondary material manufacturing, t*	Reject and loss from secondary material manufacturing, t	Produced secondary material, t
Plastic (2015)	31,277	270,816	15,304	1,189	14,268
Plastic (2018)	21,542	291,980	33,997	6,753	24,541

* waste received for industrial manufacturing of secondary materials

- Domestic supply refers to separately collected municipal plastic waste
  - The development of systems supporting plastic waste recycling are still ongoing
    - i.e. currently no functioning system for the recycling of agricultural plastic waste
- The data regarding plastic used in energy production, refers to the estimated amount of plastic among the mixed MSW and mixed C&DW
- *Produced secondary material* data obtained from company surveys from major players in the field
    - No data on small companies possibly utilizing waste
- Plastic waste ends up in secondary material production in relatively small quantities
  - Enhanced collection methods and increased efficiency in municipal solid waste and construction waste sorting may provide a method with which to redirect more of this waste flow to the secondary material cycle

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Data Sources & Uncertainties: Metal Waste

- Uncertainties:
  - Uncertainties regarding demolition statistics related to the absence or generalizations of recorded building properties
  - No data were available on the quantities of metal received, processed and forwarded by scrap dealers
    - Obtaining this information would have made it possible to compile comprehensive statistics on the collection of metals and reject during collection/processing
- Aggregated, mixed classes such as Mixed metallic packaging and Other mixed metallic wastes were difficult to use, since only their total amount was readily available and manual disaggregation was necessary to separate individual metals

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Results: Metal Waste

Figure 10. The summary supply table for metal waste in 2015 and 2018 in Finland.

Material	Domestic supply, t*	Import, t
Metals (2015)	466,613	851,546
Metals (2018)	690,146	910,722

* collected metal waste

Figure 9. Figure 3. The use and production of secondary materials from metal waste in 2015 and 2018 in Finland.

Material	Export, t	Raw materials for secondary material manufacturing, t*	Reject and loss from secondary material manufacturing, t	Produced secondary material, t
Metals (2015)	451,812	514,614	26,418	1 339,742
Metals (2018)	622,536	497,211	24,200	1 383,733

* Waste received for industrial manufacturing of secondary materials

Table 8: import, export and receival for secondary material manufacturing of metallic waste

Material	Import, t	Export, t	Received waste for secondary material production (incl. import), t
Iron & Steel 2015	813,728	358,207	1 295,571
Aluminium 2015	13,244	52,123	
Copper 2015	19,878	22,807	38,267
Mixed metals 2015	1,373	181	32,322
Iron & Steel 2018	877,493	489,728	1 323,895
Aluminium 2018	12,803	80,139	
Copper 2018	11,019	29,675	41,376
Mixed metals 2018	2,837	4,472	42,662

- Data on the amount of received metal waste for secondary material production were considered comprehensive, unlike data on the beginning of the waste cycle, i.e. generation, collection and processing before the supply to secondary material production and reject from these activities were lacking available data
- Metal waste has been estimated to cover approx. 2% of mixed household solid waste and 4-12% of mixed construction and demolition waste from which 8% was used in this study
  - The metal contained in the mixed waste is collected for recycling either before or after incineration
- The amounts of iron, steel, aluminium and copper were obtained from the customs statistics and VAHTI/YLVA together with data on the reported primary industry of the enterprises.

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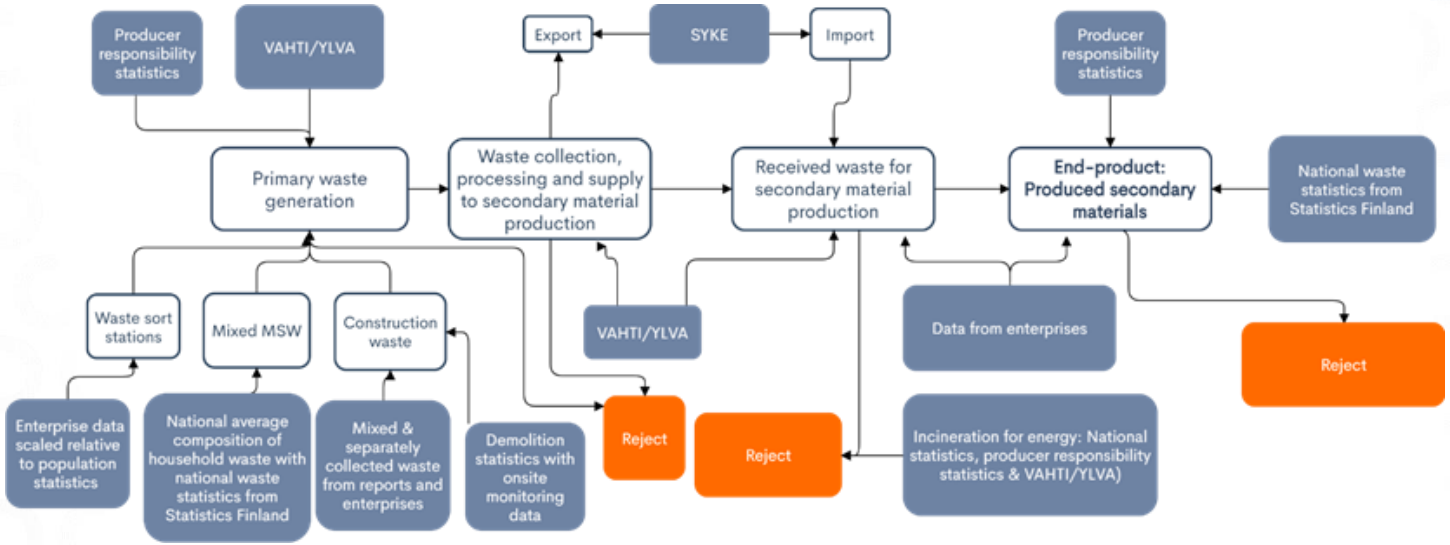
Data Sources & Uncertainties: Wood Waste



- Uncertainties
  - Inaccuracies in the demolition statistics caused uncertainties in the data regarding wood waste generated in demolition of buildings
  - No available data on the amount of bulky wood waste coming from households. The amount of wood waste in mixed MSW has been estimated to be 1,5%

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Results: Wood Waste

Figure 19. The summary supply table for wood waste in 2015 and 2018 in Finland.

Material	Domestic supply, t*	Import, t
Wood 2015	528,373	48,000
Wood 2018	541,092	30,000

* collected wood waste

Figure 16. The use and production of secondary materials from wood waste in 2015 and 2018 in Finland.

Material	Export, t	Energy production	Raw materials for secondary material manufacturing, t*	Reject and loss from secondary material manufacturing, t	Produced secondary material, t
Wood 2015	25,000	-		-	27,855
Wood 2018	40,000	-		-	52,776

* Waste received for industrial manufacturing of secondary materials

- Domestic supply includes the estimate of C&DW, wood packaging waste from producer responsibility statistics and wood waste from sorting stations
- Produced secondary material amounts were obtained from producer responsibility statistics and include the repair of wooden pallets
- Company inquiries failed to obtain additional information on the utilization of wood waste for secondary material production, the contacted companies often utilizing industrial by-products rather than wood waste
- Wood waste rarely ended up in secondary material production and most were utilized in energy production

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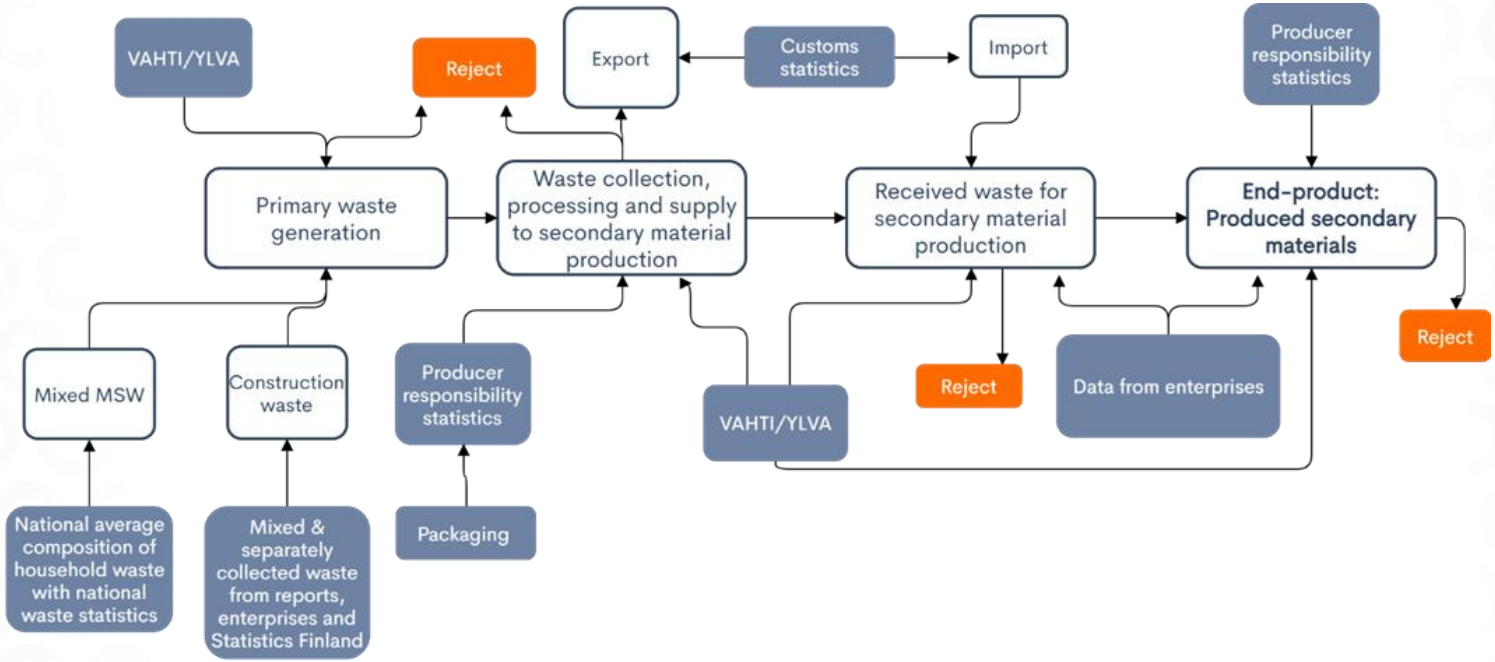
Data Sources & Uncertainties: Glass Waste



- Uncertainties:
  - Lack of comprehensive data on glass waste from demolition and construction of buildings
  - No data available to estimate the amount of reject during waste cycle

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Results: Glass Waste

Figure 22. The summary supply table for glass waste in 2015 and 2018 in Finland.

Material	Domestic supply, t *	Import, t
Glass 2015	115,565	22,220
Glass 2018	120,735	21,535

* collected glass waste

Figure 18. The use and production of secondary materials from glass waste for years 2015 and 2018 in Finland.

Material	Export, t	Energy production, t	Raw materials for secondary material manufacturing, t	Reject and loss from secondary material manufacturing, t	Produced secondary material, t
Glass 2015	47,109	35,171	77,212		115,582
Glass 2018	32,324	30,438	47,635		161,507

* Waste received for industrial manufacturing of secondary materials

- Domestic supply figure comprises data from construction and demolition and separately collected glass waste in MSW
  - Glass sorting is already moderately efficient and very little ends up in mixed household waste
    - According to the national average composition of mixed MSW from households, approx. 2% of mixed MSW consists of glass
- The import and export volumes were based on customs statistics
- The amount of raw materials for secondary material manufacturing were obtained from VAHTI/YLVA
- Together with data from producer responsibility statistics -> The amount of produced secondary materials

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More accurate supply & use tables 2015

NACE identity	23	E	G		
Primary waste generation 2015, t	Manufacture of other non-metallic mineral products	Water supply and waste management	Trade	Import	Total
Glass*	36 228,9	19 879,1	1 905,8	22,2	580 356

NACE identity	20-22	D	F	
Received material for secondary materials production 2015 t	Chemical industry	Energy supply	Construction	Total
Glass*	36 228,85	11 581,43	1 905,82	49 716,1

- Separation of individual contributing industries possible
  - Rows: products, in tons. One product per row.
  - Columns: single or aggregated industries
  - If compiled for several years, temporal differences can be seen
    - Variation in contributing industries between years, etc.
  - Provided as an Excel file with separate sheets for supply and use
  - Currently based on VAHTI/YLVA data

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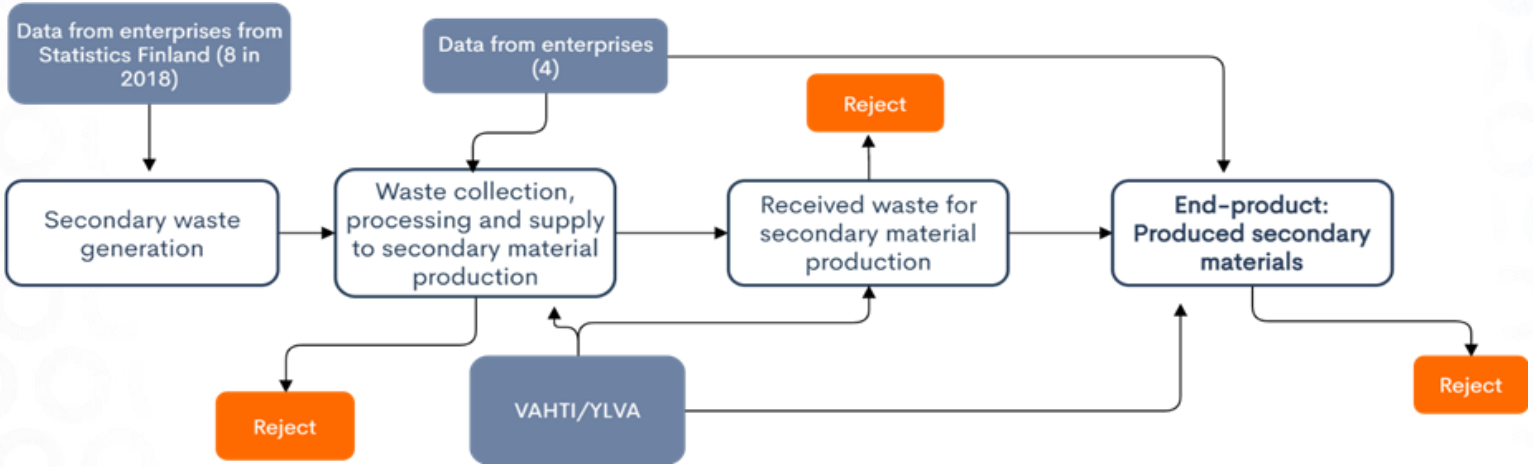
Data Sources and Uncertainties: Mineral Fractions from Processed Slag



- Uncertainties:
  - The data on the generation of mineral fractions from processed slag of waste incineration were obtained from incineration plants for year 2018. Data not collected for year 2015.
    - Uncertainty about this data were related to e.g. incinerated material and whether the incinerated material was defined as waste
  - No data available regarding reject
  - In the VAHTI/YLVA database, all slag and ash from any kind of thermal processing were reported in the same aggregated class, causing error in the estimates and making it impossible to distinguish the amount of slag from waste incineration

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Results: Mineral Fractions from Processed Slag

Material	Domestic supply, t
Mineral fractions from processed slag, waste incineration, 2015	198,417
Mineral fractions from processed slag, waste incineration, 2018	285,981

* Collected waste

Figure 20. The use and production of secondary materials from mineral fractions from processed slag from waste incineration in2015 and 2018 in Finland.

Material	Export, t	Produced secondary material, t
Mineral fractions from processed slag, waste incineration, 2015	1271	117,201
Mineral fractions from processed slag, waste incineration, 2018	-	278,295

- The exported amount was obtained from company surveys
- In regards of produced secondary material:
  - Slag gets treated to recover valuable metals
    - Some companies recover metals before incineration, eliminating the need for separation of metals from slag while some companies recover metals after incineration (no data from incineration plants for 2015)
    - Comprehensive waste statistics requires information from both waste generation and treatment companies
  - The difference between the *domestic supply* and *produced secondary material* were caused by storage

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Challenges

- Missing information on primary waste generation
- Waste is not always treated in the same year it is generated (storage)
- No data on small waste shipments that do not require customs declaration or permits
- Due to reporting practices, it is possible that the same waste streams are reported multiple times at different points in the waste cycle, resulting in duplicate calculations
  - This is because VAHTI/YLVA database is originally designed for compliance monitoring, not for material flow analysis
  - Aggregated data unsuitable for material-specific, precise accounts
  - i.e. ”paper & cardboard” and ”concrete & tiles” waste reported as aggregated classes
    - Needs to be manually reclassified, very work intensive and potentially inaccurate due to lack of precise data
- Waste mixtures with varying compositions and estimates were based on generalizations (i.e. mixed construction & demolition waste and municipal solid waste)

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Challenges

- Several routes of waste generation, with information spread across various platforms and sources.
- Concrete waste as an example:
  - For instance, facilities without Regional State Administrative Agency permits do not show in compliance monitoring database VAHTI
    - To be remedied: current compliance database will in future contain facilities with municipal environmental permits
  - Neither does direct use on demolition sites (no permits needed)

→ Several data sources needed. Data needs to be collected directly from companies, and even then it may not be available or useful.

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Conclusion

- In general, the concept proved to be functional and scalable
- Data quality and availability varies greatly by material
- Labour-intensivity, insufficient data collection systems on company-level; no demand from the public power to operators; compliance monitoring system does not support the compilation of secondary material accounts
- Certain materials (e.g. paper) subject to material flows such as littering, burning in households etc. which couldn't be estimated at all
- Complexity in waste material flows varies:
  - Amount of operators and facilities varies together with the complexity of the material chain
  - Number and production volume of potential end-uses varies
- The same data sources not suitable for all material types

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Conclusion

- The current waste statistics tends to categorize waste types and provide data in an aggregated form, making it more difficult and uncertain to utilize the data in accurate, material-specific waste accounts.
- Manual disaggregation not a sustainable solution since the amount of data can be massive
- It is probable that certain material flows, such as product packaging are very difficult to access for an accounting perspective due to the massive variation of potential products and different retail packaging types in transit.
- Producer responsibility schemes and EU-wide waste reporting provides data needs that drive for development in availability of open data for different applications.

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Thank you for your attention!

- Annika Johansson, Henri Virkkunen, Hannu Savolainen, Tiina Karppinen & Jani Salminen
- Finnish Environment Institute, Centre for Sustainable Consumption and Production
- ENVECO webinar, 25.1.2021