Research Paper Appendices

V2

Resource City

Tapping into Local Production in Apeldoorn

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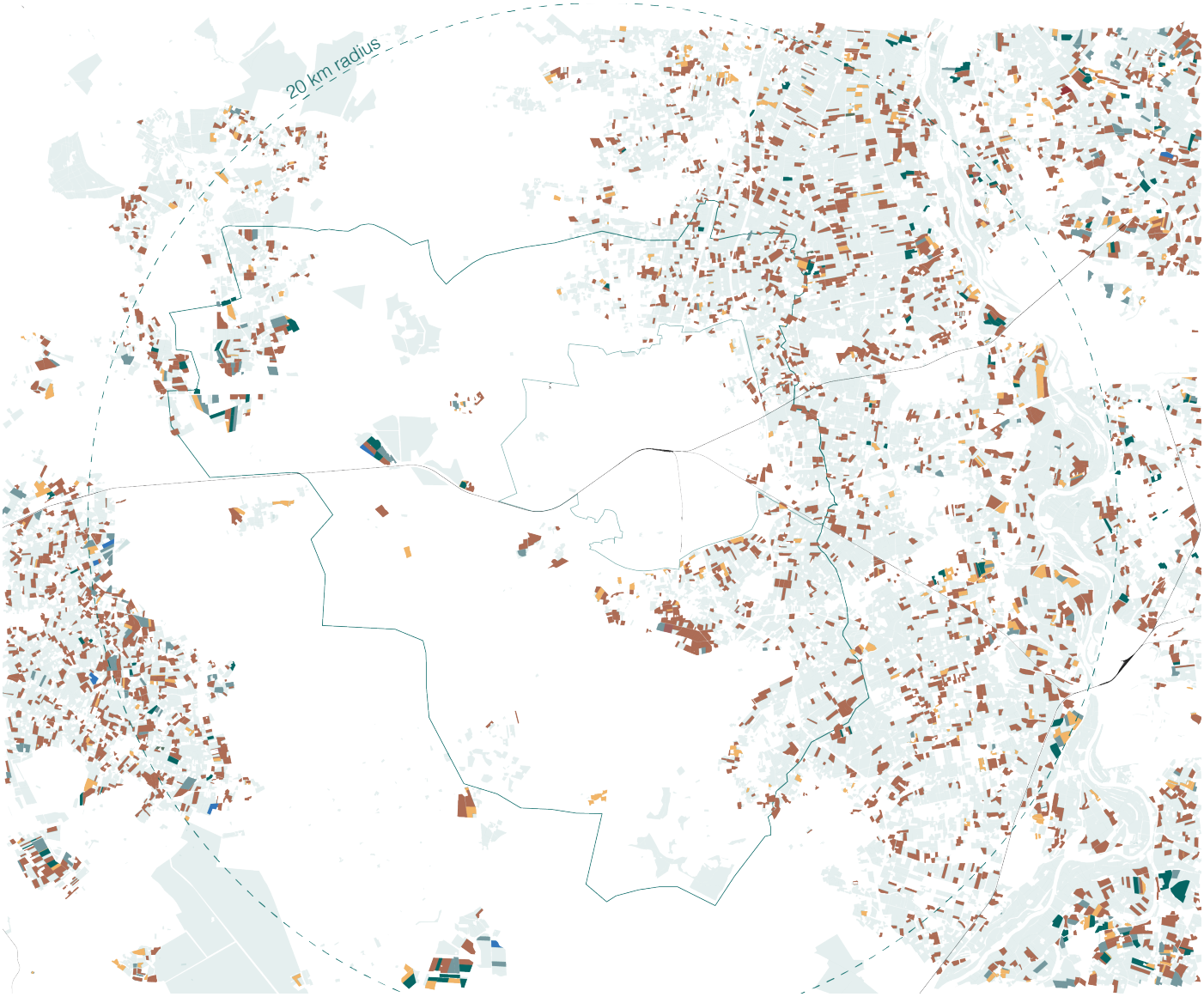
Content

Appendix A: Agriculture

A.1: Crop Plots and Agricultural Land Distrubution



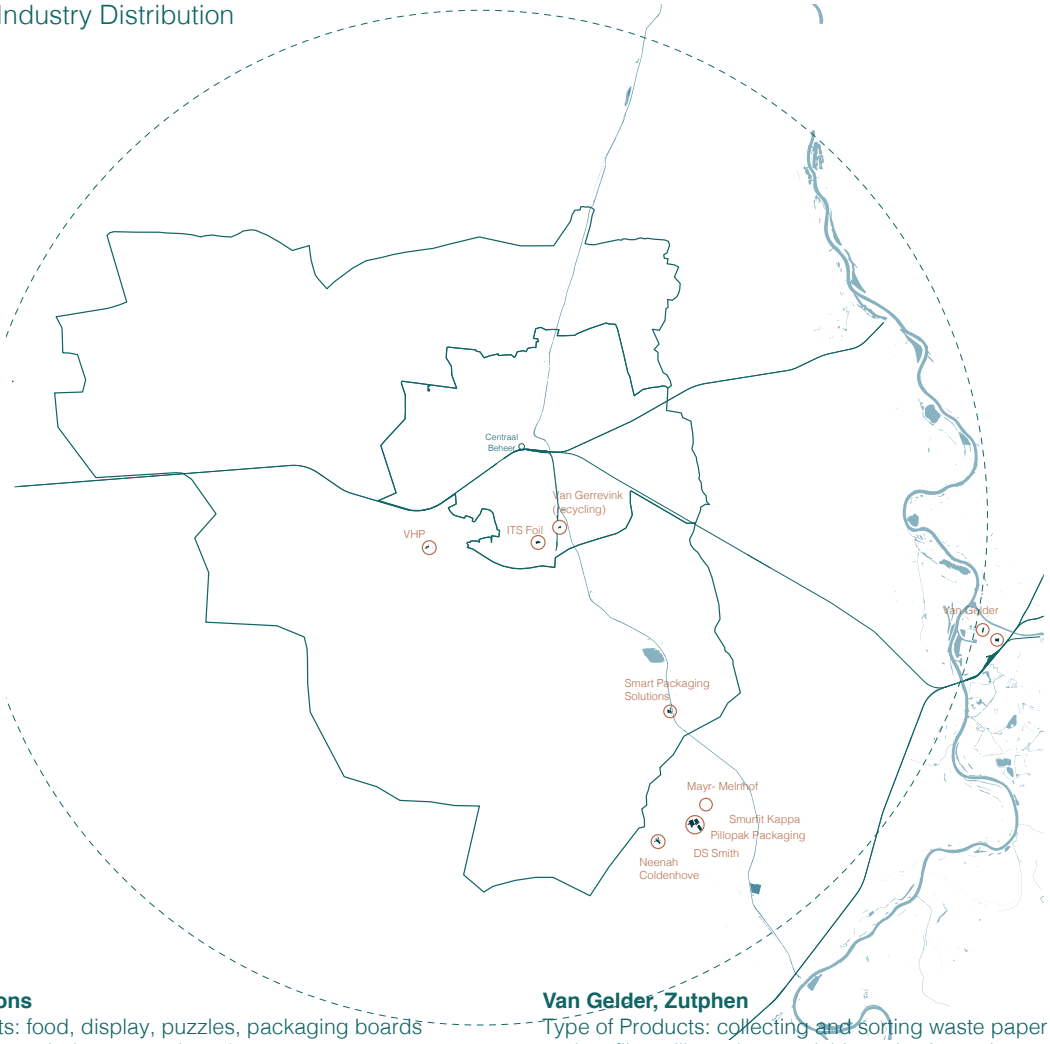
Apeldoorn Surrounding Crop Plots Map (by author)

	Area with 20 km radius of City Centre (Hectares)	Total Annual Production Gelderland (Tonnes)
Meadow Grassland	4989	2163000.00
Corn (Silage)	6733	2119000.00
Cereals/Grains	985	62456.00
Potatoes	698	246564.00
Sugar Beets	537	212000
Floriculture	96	
Hemp	6.91	337.00
Miscanthus	6.68	
Marginal Land	59.5	535 (speculative biomass)

Source: Information retrieved from CBS and GIS mapping.

Appendix B:

B.1 : Paper Industry Distribution



Solidus Solutions
Type of Products: food, display, puzzles, packaging boards
Raw Material: Recycled paper and card

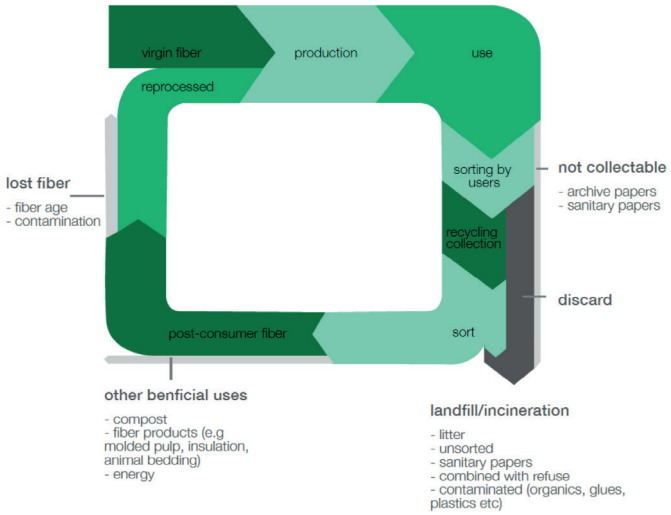
VPH Apeldoorn
Type of Products: Banknotes
Quantities of Material/Size of Company: up to 6,500 tons

Mayr- Melnhof Mill, Eerbeck
Type of Products: Folding cardboard for food packaging
Quantities of Material/Size of Company: 200 Employees in Eerbeck
Raw Material: Wood pulp (not recycled paper because of hygiene standards for food packaging)

Van Gelder, Zutphen
Type of Products: collecting and sorting waste paper and trading in secondary fibres like pulp, woodchips, plastic, and waste paper
Quantities of Material/Size of Company: 120,000 tons

ITS Foil Film and Paper, Apeldoorn
Type of Products: Household packaging, aluminium foil, cling film and microwave film to baking paper, sandwich paper and coffee filters

B.2: Paper Fibre Cycle



Paper Fibre Cycle, Source: Adriaanse (2020)

Appendix C: Material References and Examples

C.1: Overview of Applications from Local Materials

Local Source	Raw Material	Building Materials	Application	Existing Products
Agriculture	Corn	Particle Board	Wall, Floor, Ceiling Panels Furniture	https://www.cornboard.com/
		Sandwich Panels	Wall, Floor, Ceiling Panels	
	Cereals (Wheat, Barley, Rye)			
		Straw Thatch	Roofing Cladding	
		Particle Board	Wall, Floor, Ceiling Panels Furniture	https://www.novofibre.com/ https://ecoboardinternational.com/
		Straw Bales	Walls Insulation	
		Particle Board (mycelium)	Wall, Floor, Ceiling Panels Furniture Insulation	http://ecovativedesign.com/home%3Cbr%3E
		Mycelium Bricks	Wall Cladding Insulation	
	Potatoes	Starch Laminates	Laminate Finishes	https://www.huisveendam.com/work/
		Particle Boards	Wall, Floor, Ceiling Panels Furniture	https://www.chipsboard.com/
	Grasses	Fibre Board		https://ecorbenelux.com/
	Miscanthus/Hemp	Particle Board Insulation Hempcrete	Wall, Floor, Ceiling Panels Insulation Furniture	https://www.grace-bbi.eu/value-chains/green-building/
	Sugar Beets	Paints and Coatings	Paints and Coatings	https://www.cosunbiobased.com/markets/industrial/paints--coatings
	Floriculture	Colour Dyes, Ornamentation	Internal Finishes Furniture Wallpaper	https://www.organoids.com/en/products/solutions/organoid-hpl/
Paper Industry	Paper/Cardboard Products	Corrugated/ Honeycomb Cardboard	Wall, Floor, Ceiling Panels Furniture	http://www.cellx.co/
		Solid Board	Wall, Floor, Ceiling Panels Furniture	
		Cardboard Tubes	Lightweight Structure, Walls	
		L, T U Shape Cardboard Sections	Wall Framing systems	
	Paper/Cardboard Waste	Paper Waste Blocks	Furniture Infill walls	http://woojai.com/paperbricks.html
		Insulation	Insulation	https://www.thermofloc.com/en https://www.everuse.com/
		PaperCrete	Structural Walls Infill walls	
		Fibre Board	Infill Wall Panels Furniture Acoustic/Ceiling Panels	
Consumer Waste	Organic	Fibre Board	Infill Wall Panels Furniture Acoustic/Ceiling Panels	https://ecorbenelux.com/
	Textiles	Insulation	Insulation	https://www.vrk-isolatie.nl/ http://www.sk-tex.com/
		Fibre Board	Infill Wall Panels Furniture Acoustic/Ceiling Panels	
Other Biomass	Green Waste (roadside grass)	Fibre Boards		https://www.grasgoed.eu/en/over-grasgoed/ https://ecorbenelux.com/
	Cattail	Reed Panels	Cladding	
Forests	Timber (Scots pine, Douglas fir and beech)	Sawn Timber	Structure (Floor/Walls/Roof) Cladding Infill Wall Panels	

C.2: Flat House/Margent Farm, Practice Architects

Source: Practice Architecture. (2019). Flat House. Retrieved December 27, 2020, from https://practicearchitecture.co.uk/project/flat-house/

C.3: Westborough Primary School, Cottrell & Vermeulen

Source: Cottrell & Vermeulen, Westborough Cardboard Building, Retrieved December 27, 2020, https://www.cv-arch.co.uk/westborough-cardboard-building/

Appendix D: Calculations
D.1: Section 3.2 Calculations

NL wheat yield = 8.5 tonnes per hectare (https://www.indexmundi.com/facts/netherlands/indicator/AG.YLD.CREL.KG),
85% of yield is quantity of straw produced
Straw Yield = 7.225 tonnes/hectare

External Wall Panels:

Hempcrete Infill
External Wall Surface Area = 7139 m² (from rhino)
Assume 250 mm thick wall
Total volume of hempcrete required: 7139 x 0.25 = 1785 m3
1 m3 hempcrete requires 100kg of hemp (Stanwix, 2014)
Total weight of hemp required: 1785 x 100 kg = **178,500 kg**
Hemp yield = 7.5 tonnes per hectare
Total harvest area required: 178.5/7.5 = **23.8 hectares**

Straw Bale Infill:
Density of straw 110kg/m3 (https://www.bre.co.uk/filelibrary/pdf/projects/low_impact_materials/IP15_11.pdf)
Assume 250 mm thick wall
Volume required: 1785 m3
Weight of straw required = 110 x 1785 = **196,350 kg**
Total harvest area required: 196.4/7.225 = **27.2 Ha**

Timber Frame:
Total length of external wall: Level 0 = 610 m, Level 1 = 565 m, Level 2 = 492 m, Level 3 = 371 m, Total = 2038 m
2038/0.5 = 4076 Studs
Volume of timber per stud 0.2 x 0.075 x 3 = 0.045 m3 (assume 200 x 75 mm studs)
Total Volume of vertical studs = 183.42 m3
Horiztonal total length = 2038 x 2 = 4076 m
Total Volume of horizontal timber = 0.2 x 0.075 x 4076 = 61.14 m3
Total Volume of timber = 61.14 + 183.42 m3 = **244.6 m3**

Agricultural Fibre Board:
External Wall Surface Area = 7,139 m 2 (from rhino)
20 kg straw required per m2 for 20 mm thick board (Arup, 2017)
Total Straw Required: 20kg x 7139 = **142,780 kg**
Total harvest area required: 142.780/7.225 = **19.76 hectares**

Internal Finishes:

Agricultural Fibre Board:
Surface Area Required: 40,627 m2 (from rhino)
20 kg straw required per m2 for 20 mm thick board
Total Straw Required: 20kg x 40627 = **812,540 kg**
Total harvest area required: 812.5/7.225 = **112. 5 hectares**
Total Straw Produced in Gelderland Annually = 53087.6 tonnes
Percentage of annual production= 812.5/53087.6 = 1.5% of annual production

Internal Partitions

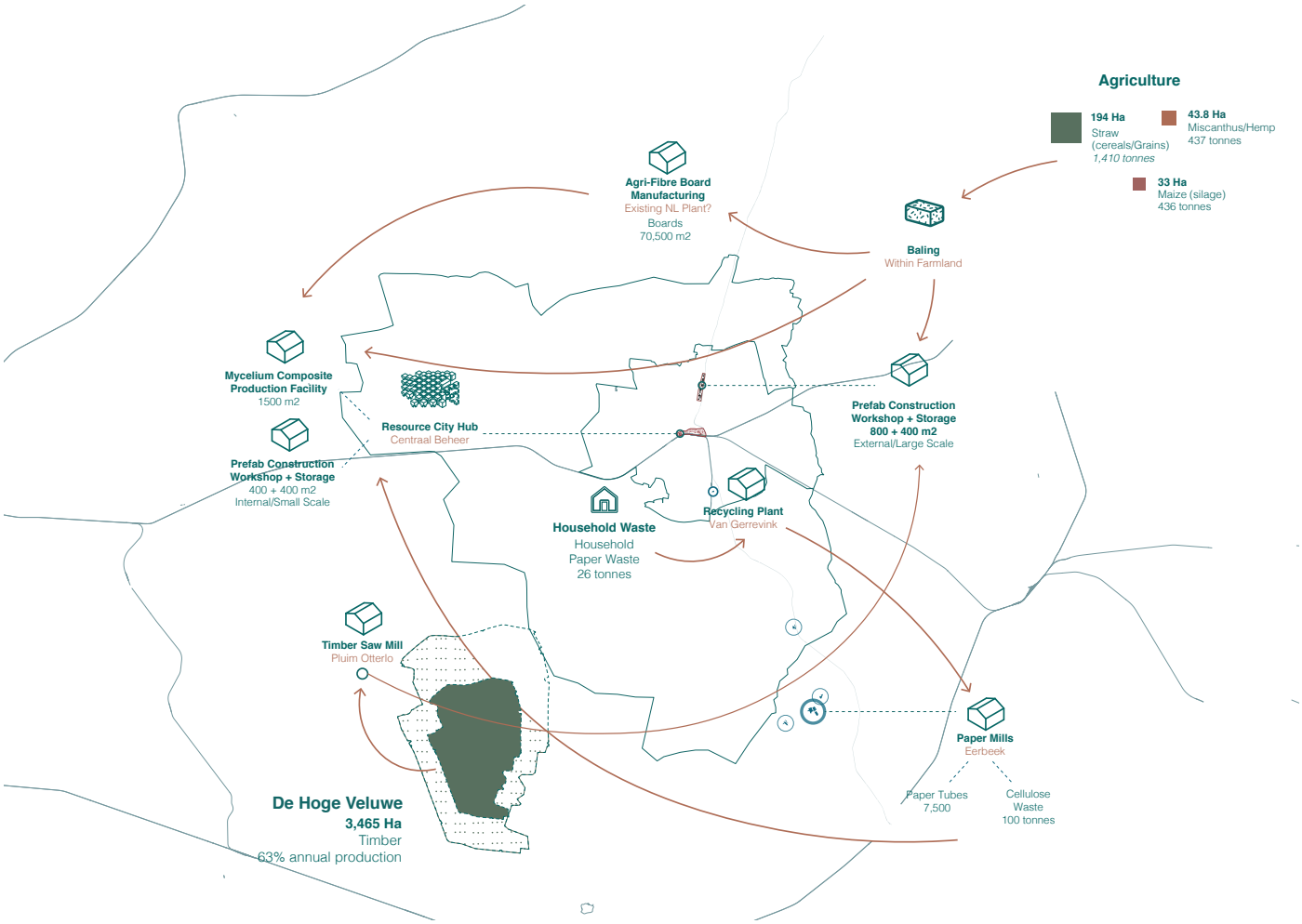
Mycelium Blockwork Partitions:
Total surface area: 8,890 m2
Assume 200 mm thickness of mycelium = 8890 x 0.2 = 1778.2 m3
186 kg of fibre per 1m3 (de Bruin, 2019)
Total Straw/Corn Stover Required = 186 x 1778.2 = **330,708 kg**
Total harvest area required for straw: 330.7/7.225 = **45.7 hectares**
Silage maize dry matter yield = 13 tonnes per hectare (https://veepro.nl/wp-content/uploads/2015/03/VeeproForageManagementsmall.pdf)
Total harvest area required for corn: 330.7/13 = 25 hectares

Cardboard Tube Partition:
Surface Area: 8890/4 = 2222.5 m2
Total Length : 2222.5/3 = 740 m
(740/0.5m) x 2 = 2963 tubes required
Paperboard 2mm thick = 1200 g/m2 (Latka, 2017)
10 mm = 6000 g/m2
Total surface area per tube = 0.22 x 3 = 0.66 m2
Weight per tube = 0.66 x 6000 = 3960 g = 3.90 kg
77% paper waste, 14% virgin fibre, 8% filler
87% of total input weight = output weight of material
Apeldoorn paper waste per year = 9,136 tonnes
9,136 tonnes = 10,321 tonnes of paper products per year
10,321/ 0.0039 = 2, 646,410 tubes

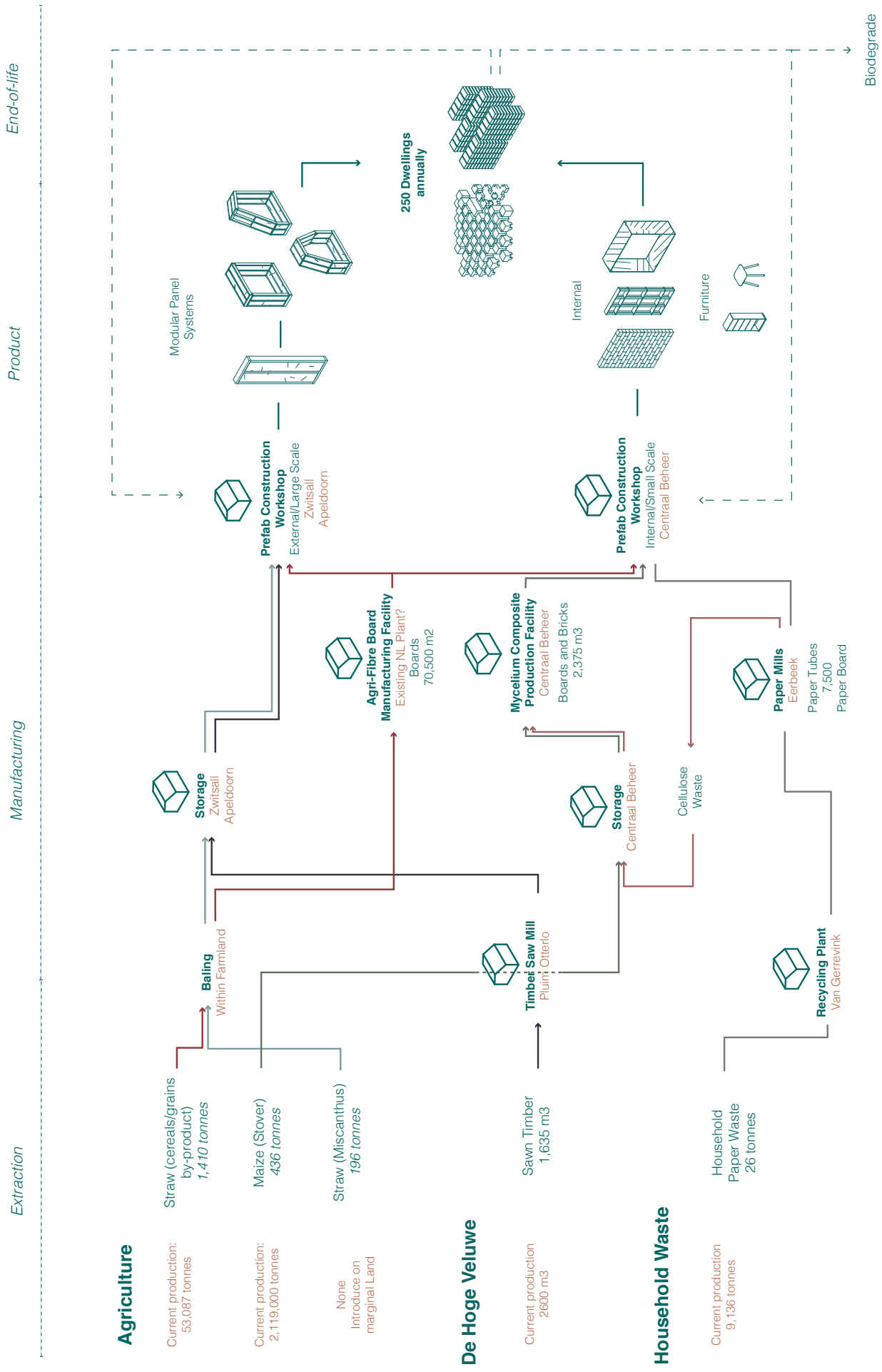
Total Agriculture Area within 20km PDOK
415,660,119 m2 (41,566 ha)

Appendix F: Proposals and Interventions

F.1: Schematic Proposal - Local Supply Chain Map



Summary of interventions for future local material supply chain


Extraction
Manufacturing
Product
End-of-life
Biodegrade
Agriculture
Current production: 53,087 tonnes
Straw (cereals/grains by-product) 1,410 tonnes
Current production: 2,119,000 tonnes
Maize (Stover) 436 tonnes
None Introduce on marginal Land
Straw (Miscanthus) 196 tonnes
De Hoge Veluwe
Current production 2600 m3
Sawn Timber 1,635 m3
Household Waste
Current production 9,136 tonnes
Household Paper Waste 26 tonnes
Baling Within Farmland
Storage Zwitsall Apeldoorn
Timber Saw Mill Pluim Otterlo
Storage Centraal Beheer
Agri-Fibre Board Manufacturing Facility Existing NL Plant? Boards 70,500 m2
Mycelium Composite Production Facility Centraal Beheer Boards and Bricks 2,375 m3
Cellulose Waste
Paper Mills Eerbeek Paper Tubes 7,500 Paper Board
Recycling Plant Van Gerrevink
Prefab Construction Workshop External/Large Scale Zwitsall Apeldoorn
Prefab Construction Workshop Internal/Small Scale Centraal Beheer
Modular Panel Systems
250 Dwellings annually
Internal
Furniture

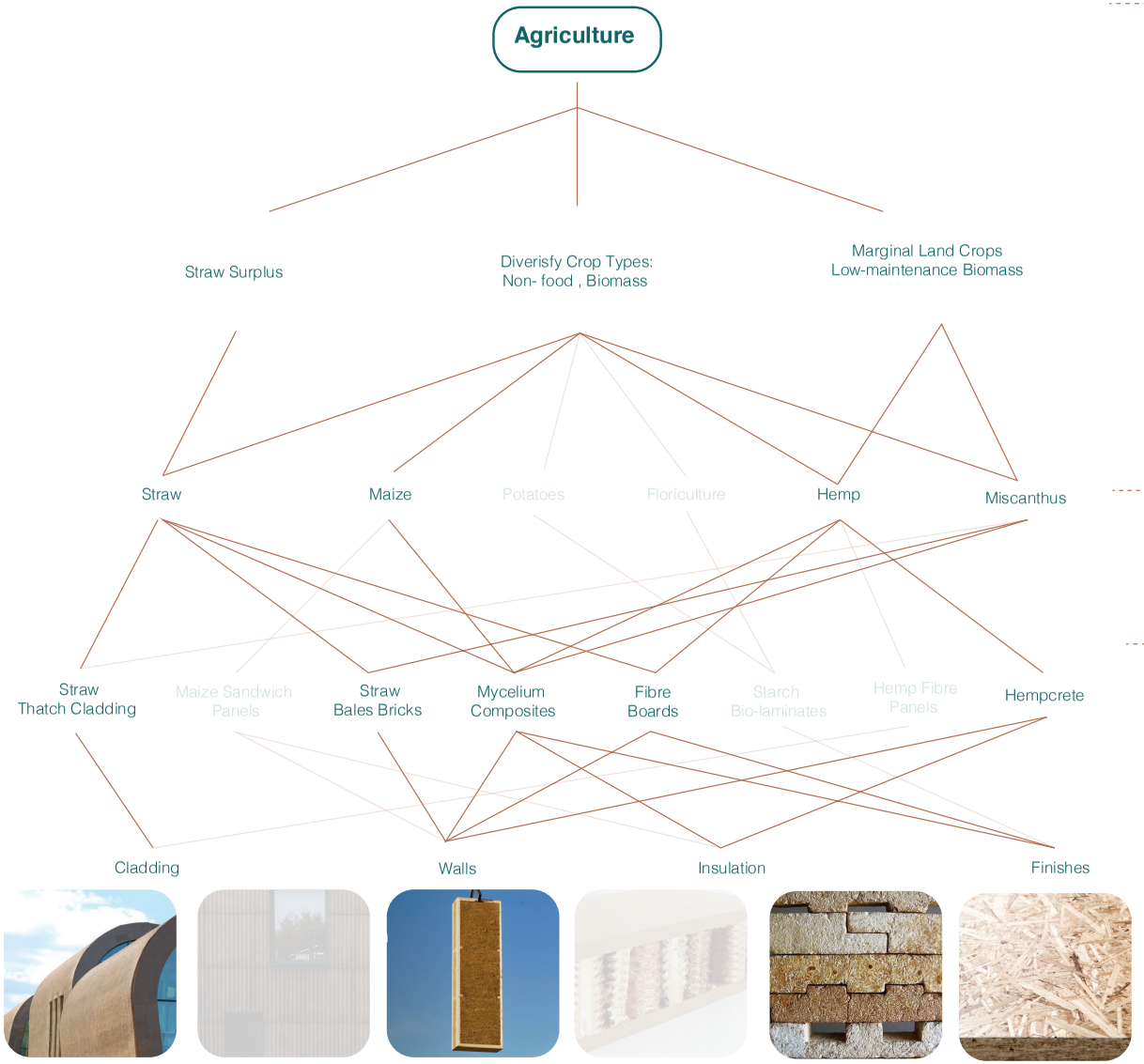
Local Source:

Opportunity:

Raw Material :

Materials :

Application :



Criteria:

Utilise Waste

Quantity Available

Renewable Source

Affordability

Design Criteria:

Design principles: Circularity+ Structuralism

Application within other residentia construction

Prefab Potential

Labour/Processing Intensity

Aesthetics

Local Source:

Paper Industry

Opportunity:

Re-purpose Waste
Add Value

Recyclable Building Material
Replace un-recyclable materials

Raw Material :

Waste Cellulose

Materials :

Mycelium Composites
Fibre Boards
Loose Insulation
Papercrete
Paperwaste Blocks
Paper Tubes
Paper Board
Corrugated/Honeycomb Boards

Application :

Walls
Insulation
Finishes


Criteria:

Utilise Waste

Quantity Available

Renewable Source

Affordability

Design Criteria:

Design principles: Circularity+ Structuralism

Application within other residential construction

Prefab Potential

Labour/Processing Intensity

Aesthetics

G.3: Materials from the Veluwe and Urban Waste