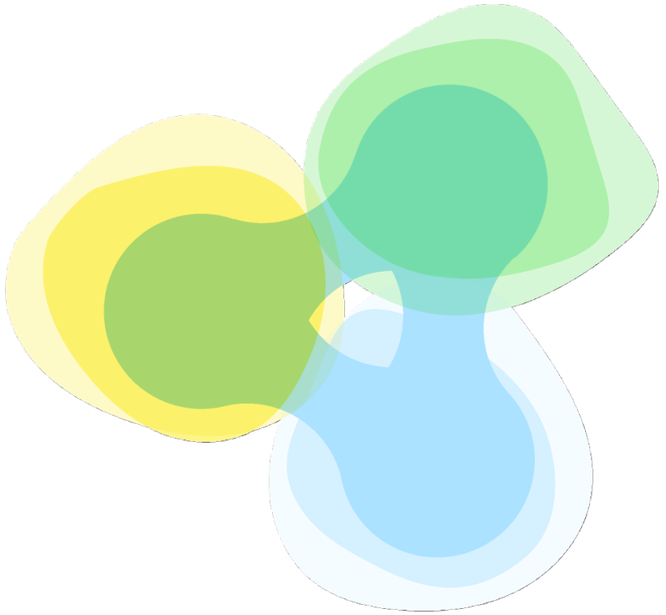


New European Bauhaus

beautiful | sustainable | together

New European Bauhaus

Circular Housing in Ukraine (Project B)

Mirjam Niemeyer, Zürich/Kyiv • Natasha Kozub, Porto/Kharkiv

WHY?

As of 8 Sept 2022 at least 15,300 high-rise buildings, 115,900 private houses, 44 social centers, 1,118 educational institutions have been **damaged in Ukraine due to the war**

The need in new construction and reconstruction after the war will be huge.
Re-building of Ukraine should be done as carbon neutral as possible.
Ukraine has already taken course on the green recovery (Lugano, Berlin) and should continue.

WHY?

About half of the total CO2 emissions of a building arise during the construction process and the production of the material components. It is not enough to simply optimize the energy efficiency of a house.

To reduce the construction industry's contribution to global warming, its immediate decarbonisation is necessary and cannot only depend on incremental CO2 savings over the life cycle of a building but **must include the planning and construction process.**

WHAT?

Circular construction means to develop, use, and re-use buildings, sites and infrastructure without unnecessarily exploiting natural ressources, polluting the environment and damaging ecosystems.

Building in a way that is economically sound and contributes to the **well-being of people, animals, nature and the earth.**

AIM
of this report is

- Provide an overview of the legal framework
- identify local resources for cicular construction
- introduce circular construction technologies
- make recommendations for future steps

Mirjam Niemeyer • Natasha Kozub

Focus 1

Legal framework and knowledge on circularity

Focus 2

Demolished buildings: Reuse of building components and recycling of building materials

Focus 3

Circular construction techniques using ukrainian ressources

Focus 4

Renovation of buildings applying circular construction technologies

Focus 5

Strategic recommendations for future steps

Mirjam Niemeyer • Natasha Kozub

Legal framework and knowledge on circularity in UA

Important abbreviations and terms

* CDW - construction and demolition waste
* RA - recycled aggregates - endproduct of recycling of CDW

Related UA legislation until 2022

2017: The **National Strategy on Waste Management** until 2030 was passed: it sets out the course for CDW recycling and for the sustainable usage of resources in construction

2019: The **National Plan on Waste Management** until 2030 was passed: it lays out a plan for the new laws about different types of waste; but the CDW waste is not mentioned; for the present moment only the foundational law "On Waste Management" was passed

2020: The **law "On providing construction products to the market"** will take force from 1 Jan 2023
This law sets a requirement for sustainable use of natural resources by reuse and recycling, by design for longevity and by usage of ecologically friendly materials

2021: over 500 **national standards identical to EU harmonized standards for construction products** were passed in order to comply with the regulation 305/2011 of EU Parlament.

From **January 1, 2023**, **Ukraine will** become the 32nd country in the world to **implement EU Regulation No. 305/2011** that lays down harmonised conditions for the marketing of construction products.

Related UA legislation after 24 Feb 2022

June 2022: The **law "On Waste Management" is the foundation of the future waste management legislation**; it will be followed by sectoral laws and by regional and local waste management plans; according to expert (Igor Lysenko, PAEU) the process to set up legislation for waste management on all levels will take at least 3-4 years from now.

Aug 2022: the **"National Standard on Life Cycle Costs for Builidngs"** to stimulate energy- and resource-efficient construction.

Aug, Sept 2022: several **laws were changed and national building standards updated** to deepen the state's course on energy saving and comprehensive thermal modernization of the country

Sept 2022: The **new law "On the Public Health System"** baned usage of asbestos in new building materials but didn't introduce any measures for existing buildings with asbestos.

Sept 2022: the new **"Procedure for handling demolition waste generated by hostilities"** was issued; it introduced categories of CDW waste and how they can be treated, while hazardous waste (including asbestos) was not addressed.

Sept 2022: Changes to the regulation #590 about financing of municipal activities: Municipalities are limited in spending their budgets during the martial law to certain activites and demolition waste management is NOT one of them

Recent key events in the field of circularity in UA

There is a lot of attention from international organizations to the problem of war demolition waste in UA

Starting from Sept 2022 there was a **series of online and offline networking events for municipalities, professionals in the fields of waste managements**, ecology and environment and actors in the field of reconstruction.

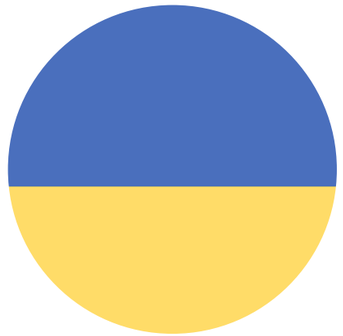
Pilot project for reconstruction of buildings using the demolition debris in city of Hostomelis being developed by Neo Eco company supported by French government.

Pilot project for housing using the demolition debris in Kharkiv is being developed by Norman Foster Foundation and Arup Berlin in coopertion with local architects and city administration

Potential cooperation between UA government and GreenMix company (Israel) to build a **first RA producing plant in UA was announced in Aug 2022** though there are no recent developments oin the news

All this contributes to the awareness of all stakeholders on the current status, challenges and potentials of CDW management; BUT other aspects of circular construction are not discussed yet.

Conclusions on legal framework for circularity in UA



Potentials

- After the full scale invasion and after Ukraine became a candidate to EU member, the **state regulation of construction industry is changing rapidly to become harmonized with EU** regulations.
- **Most progress** is happening **in the field of waste management and energy-efficiency of buildings**.
- Ukraine has communicated **strong intention to green recovery and sustainable development** in the last months

- **Challenges**
- **no national strategy for circularity** in construction industry.
- New laws are “moderate” and have recomendational character rather than prescriptive. **Control mechanisms are not defined** or not working.
- Urgent **need for national standards** for secondary and recycled building materials setting requirements and making them marketable products.

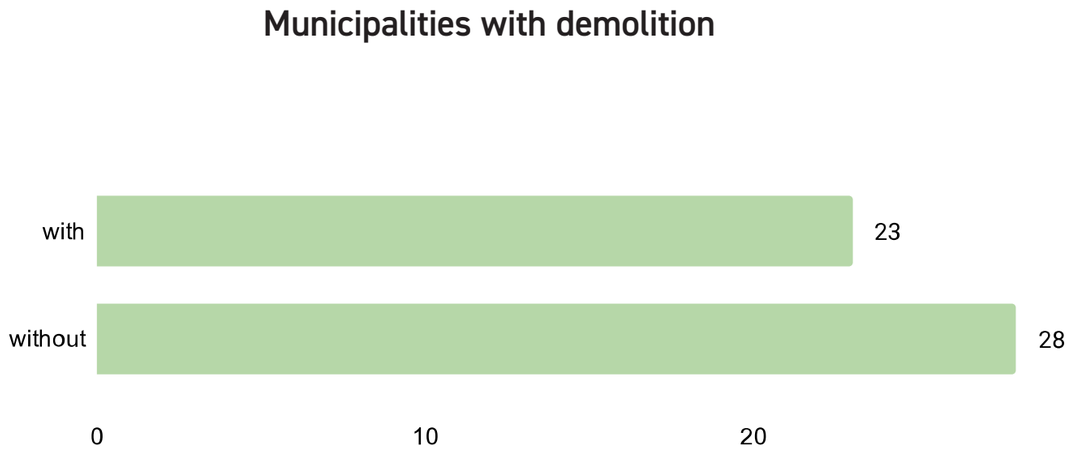
Recommendations

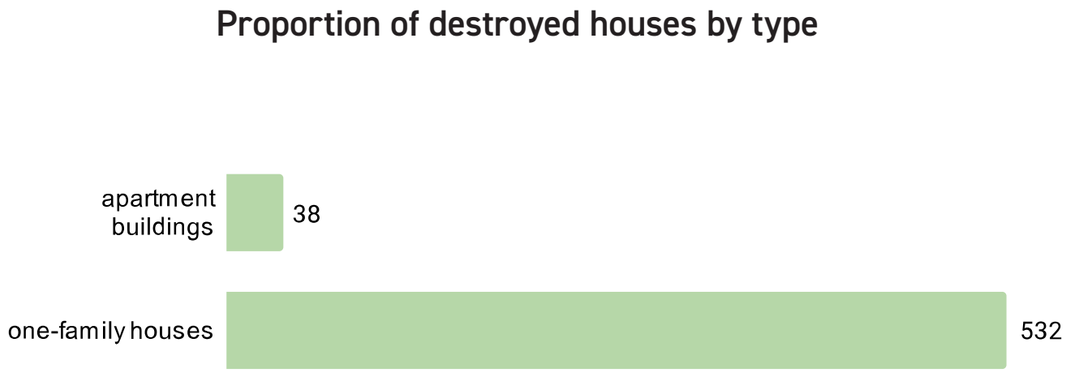
- Systematic review of construction industry regulations and **establish functional and supportive legislative framework** to improve circularity in construction. Cooperation between many stakeholders: investors, developers, producers of building materials, etc needed
- Develop similar **measures** as **for** recent energy-efficiency of buildings to other aspects of **circularity in consctruction and recycling.**

Demolished buildings: reuse of building components and recycling of building materials

Results of the survey on demolition waste in UA municipalities

Survey form Oct 26 to Nov 4 2022. Survey was spread among
UA municipalities by Covenant of Mayors East.
51 replys were collected (few were deep and informative)

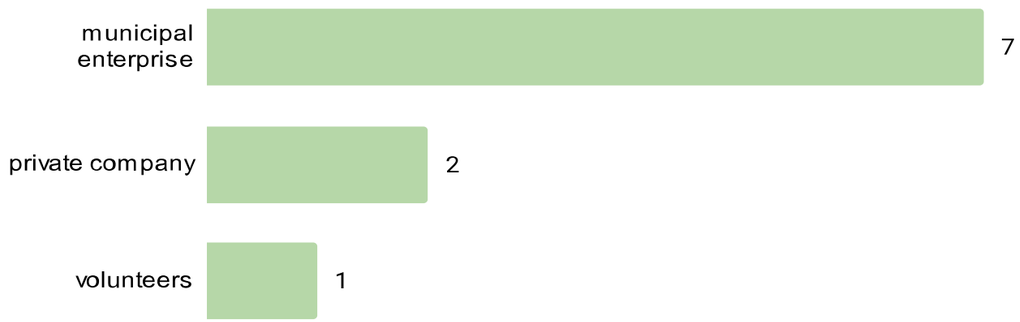




Results of the survey on demolition waste in UA municipalities

Who commissioned the demolition?

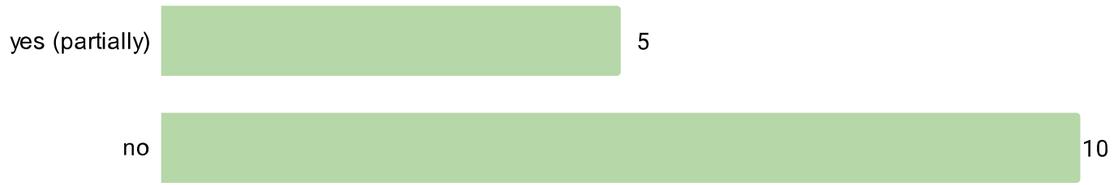
Who performed the demolition?



Destination of demolition waste

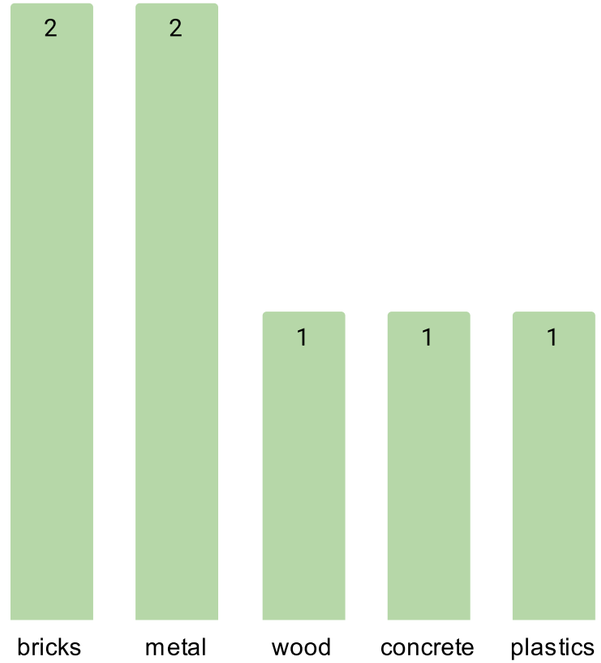
Results of the survey on demolition waste in UA municipalities

Is any sorting done for demolition waste?



Are there companies that process CDW nearby?

Which categories are sorted out?

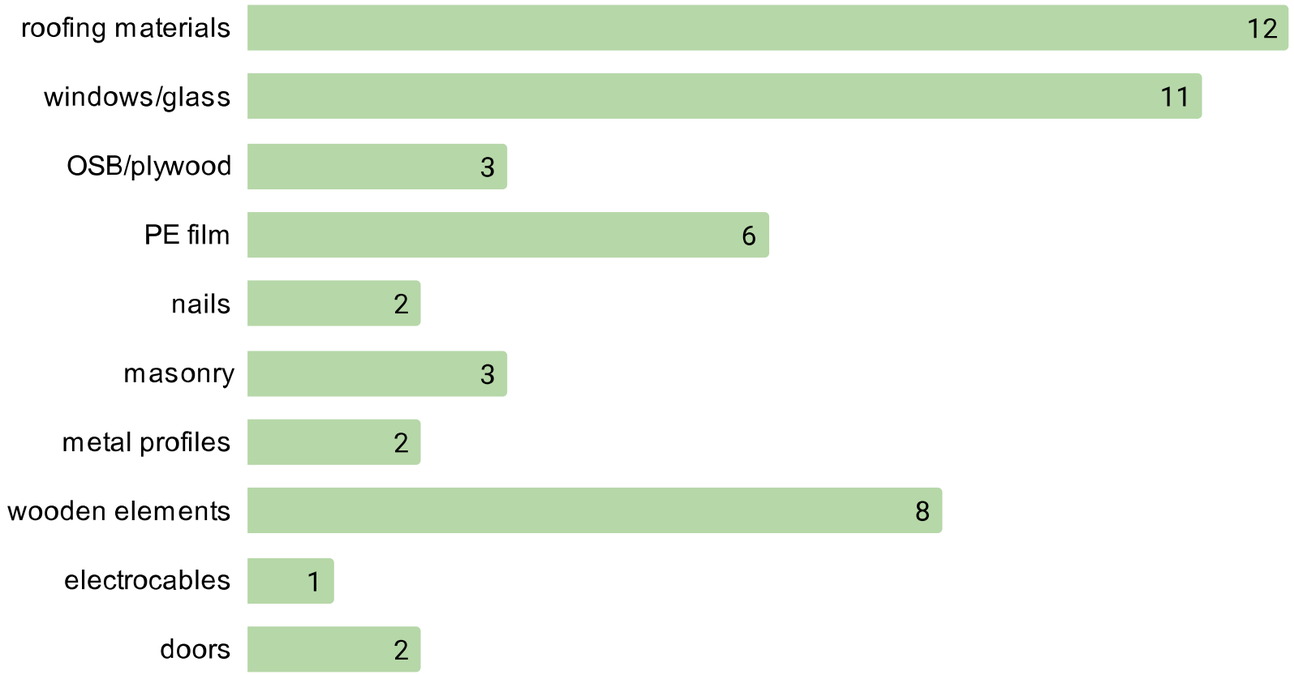


Results of the survey on demolition waste in UA municipalities

Is there possibility to reclaim and reuse building elements?

Could the relaimed elements be useful to DIY builders?

What kind of materials are needed urgently now?



Conclusions from the survey on demolition waste in UA municipalities

Majority of **municipalities understand the necessity** and have been given the procedure for demolition waste management from national government, but **for the time of martial law they are limited in their spendings** to the few priority activities and waste management is NOT one of

Barriers for sorting and recycling of war demolition waste named by municipalities:

- huge scale of demolitions
- time pressure
- no capacity (people)
- little (basic) know-how
- no equipment for sorting and recycling
- no money for dismantling of buildings and recycling
- no money for appropriate transportation/ loading/unloading
- no storage space
- the goal is not clear to municipalities
- bureaucratic issues

Municipalities can not at the moment cope with the amounts of demolition waste by themselves, therefore a **national program is needed to provide know-how and financial help** for urban mining activities: Careful deconstruction, sorting, recycling equipment, storage grounds, etc

Mapping of demolition

Several initiatives map the demolitions - two examples:

Most demolitions are concentrated near the frontline, on occupied, and liberated territiries. But massive rocket strikes caused also many demolitions all over the country.

Destroyed Infrastructure

recovery.gov.ua map provides figures on destroyed infrastructure by types: schools, roads, hospitals, housing; separately for each region

Damages of civilian infrastructure by period: green - in November; red - before

maphub.net/Cen4infoRes/russian-ukraine-monitor
interactive map shows infrastructure damages by month

Assessment of demolition

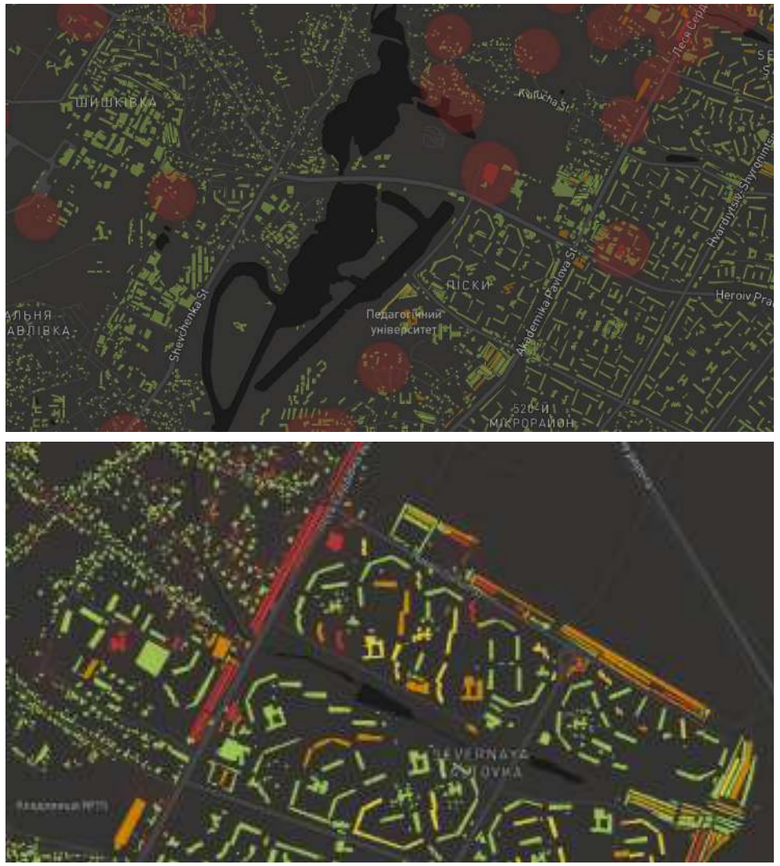
Satellite imagery provides for:

- first steps in damage assessment
- provides overview and focus/target areas
- Preliminary results
- Allows for debris estimation

Existing initiatives in the field:

- RebuildUA.net - sattelite imagery and damage accessment; 58 locations analysed (as for 6 Dec 22)
- damaged.in.ua/satellite-data - satellite imagery and damage accessment, partners: RebuildUkraine and Culver Aviation; 61 locations analysed (as for 6 Dec 22)
- uadamage.com - sattelite imagery and automatic damamge accessment by neural network; 51 locations analysed (as for 6 Dec 22)

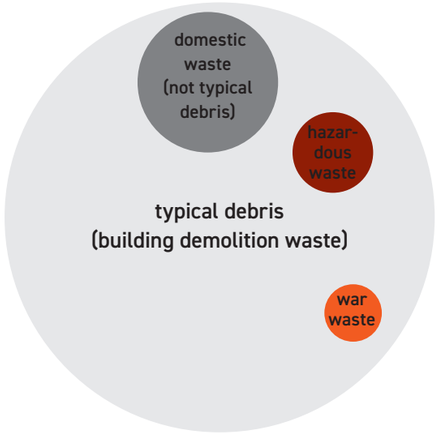
Source: rebuildUA.net



Source: uadamage.com, Kharkiv

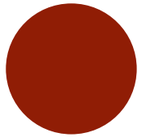
Composition of demolition waste

The morphology of war debris is more complex than that of the “normal” demolition debris, because usually before the buildings are demolished they are empty from all household items: furniture, textiles, home appliances, electronics, medicines, organic parts, etc. The war waste, i.e. parts of exploded and unexploded missiles, is added to this. The diagram below shows the composition of the debris conceptually, the exact proportions were not calculated by anyone.



Dobrobat is a network of groups of volunteers that provide help with waste cleaning and urgent repair throughout UA, source: Telegram channel of Dobrobat

Hazardous waste in UA



- **Debris is sent to landfills in most cases.** It contains hazardous substances and pollute soil, groundwater and air.
- These landfills are a ticking “time bomb”: Risk of extensive pollution of the environment.
- Utilization of hazardous waste is expensive and not affordable to municipalities at the moment.
- Little knowledge in society on which materials are hazardous and what are the associated risks.

Recycling regulations and companies EXIST for:

- fluorescent lamps, energy-saving lamps
- batteries and accumulators
- WEEE (waste electric and electronic equipment)
- medicine
- paints containing heavy metals

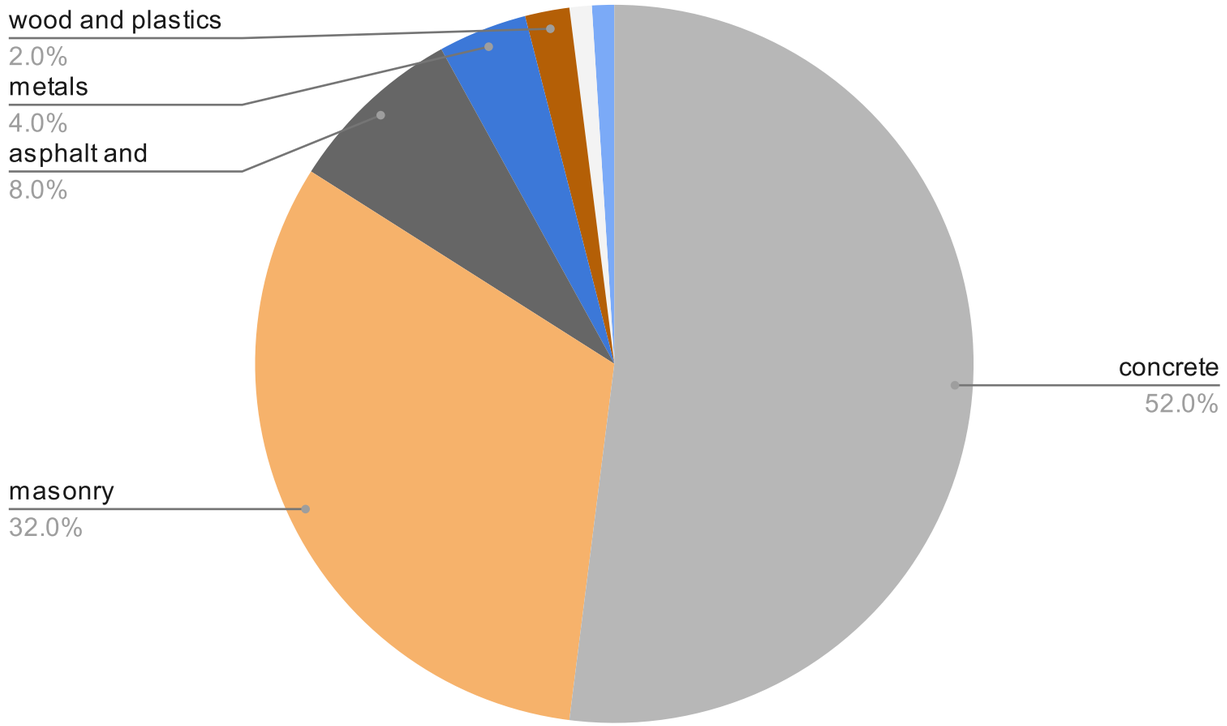
Recycling **regulations and companies DON’T exist** for:

- asbestos (part of around 60% of roofing materials in UA)
- PCBs (polychloride biphynyls)
- mercury
- other

Composition of debris

From the point of view of circularity, the recycling potential is proportional to quantities of materials:

- concrete and masonry sum up to more than 80% and have big economic potential;
- metal recycling is already established and economically viable;
- small percentage for wood, pvc, gypsum, glass, mineral wool, etc. make their recycling not so profitable and, looking at other countries experience, it has to be stimulated additionally by regulations and policies, otherwise it will not establish and will remain a marginal activity driven by eco-activists.



Source: National Strategy for Waste Management until 2030 in UA, issued 2017

Concrete recycling: Status quo in UA

The bottleneck for concrete recycling in UA is the expensive equipment which is now owned by very few companies and municipalities:

- Two producers of equipment in UA; installation costs around 1 mio. euros
- In most cases concrete is landfilled together with the rest of the demolishion waste
- In some cases it is used as blocks resulting from deconstruction for backfilling or pavement
- Concrete from demolition debris is potentially contaminated with large quantities of asbestos, PCBs, heavy metals, and other hazardous substances; the know-how on how to clean it is absent at the moment in UA; in many cases manual sorting before crushing can be a solution

Few municipalities own crushing machines at the moment, but there is a big interest among municipalities with demolitions to get such equipment.

The war debris amounts are estimated in mlns of tonns now and the mindset of municipalities is slowly but steadily changing towards using it as secondary building material.

Concrete crusher working in Kharkiv,
Source: Facebook page of Olnova

Crushed concrete is sold by few companies and is a popular product in UA because of its lower price compared to raw aggregates (approximately, 50% lower); the demand for aggregates both primary and secondary is high because of urgent infrastructure repairs that happen at the moment

Source: online store of Budova company

Concrete recycling: Established technologies worldwide

Recycled aggregates from concrete is an established product in EU and worldwide. Most part of RA is used for roads subbase and for backfilling, only 1% is used for new concrete or cement production.

Companies producing recycled aggregates in EU:

- feess.de
- holcim.com
- theopouw.nl
- eberhard.ch

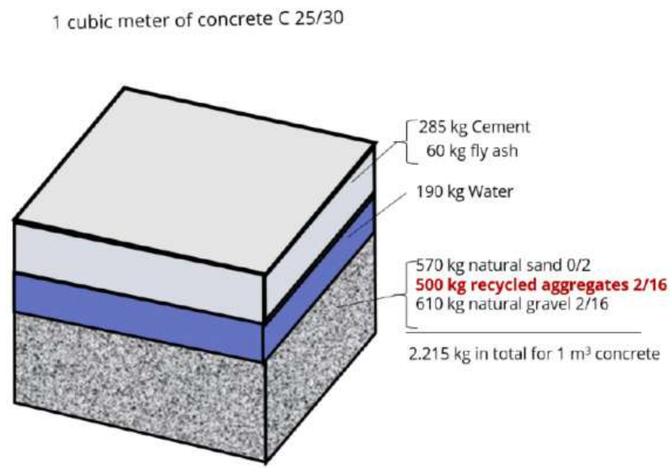
Recycled aggregates both carbonized and normal
can be effectively used for road construction

Carbon negative recycled aggregates is a relatively new and innovative product worldwide. Carbon negative or carbonated recycled aggregates are made by exposing crushed concrete to liquid CO2. This process requires the establishment of CO2 capturing industry in UA which is not present at the moment. This is most likely explained by the fact that UA has the lowest CO2 emissions costs of all the EU countries and there are corruption mechanisms to overcome the emissions quotes. So at present the market is simply not intereted in lowing CO2; but there is a hope that the situtation will change because being a candidate to EU member state UA will be obliged to lower CO2 emissions.

Company that produces carbon negative recycled aggregates and products:

- neustark.ch
- carbicrete.con

Usage of **recycled aggregates and carbonaed recycled aggregates for new concrete** is technically possible and is done in some countries (GE, CH, NL, FR), but due to specifics of recycled aggregates such concrete needs more cement if used for structural building components; while cement is the biggest source of CO2 emissions. At the same time recycled aggregates can be used for non-structural concrete blocks, and pavement elements.



Typical composition of recycled concrete
Approx. 1/3 of all aggregates can be replaced by recycled aggregates
Source: Final Conference of SeRaMCo, 2020

Concrete recycling: Cutting edge technology "carbon negative concrete”

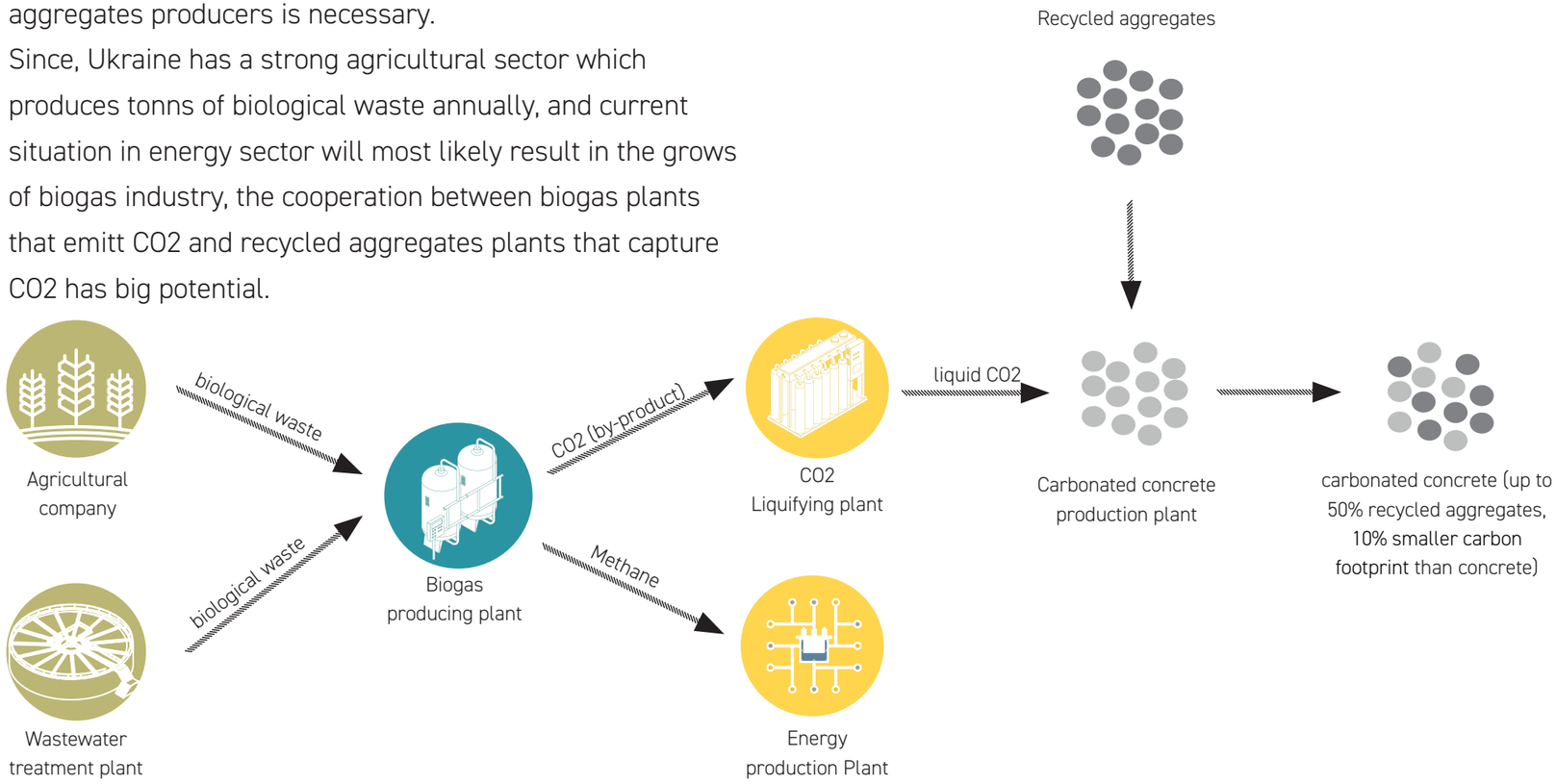
“Carbonated recycled concrete” is produced from carbonated recycled aggregates: the CO2 sequestered by aggregates is stored in the concrete. Carbonization creates negative carbon emmissions up to 10%.

During the production process of carbonated concrete more carbon is captured than is emitted making the resulting concrete carbon-negative.

Carbonization requires CO2 in liquid form; CO2 is a comon by-product of many plants: biogas, water treatment, cement production, etc CO2 is captured and liquified; recycled aggregates are combined with liquid CO2 in special autoclaves to produce carbonated recycled aggregates; these aggregates can further be used to produce carbon negative concrete.

To establish carbonated recycled aggregates industry the cooperation between CO2 producers and recycled aggregates producers is necessary.

Since, Ukraine has a strong agricultural sector which produces tonns of biological waste annually, and current situation in energy sector will most likely result in the grows of biogas industry, the cooperation between biogas plants that emitt CO2 and recycled aggregates plants that capture CO2 has big potential.



Producers worldwide:

www.neustark.com (concrete aggregates)

www.carbicrete.com (concrete elements)

Concrete recycling: Cutting edge technology SmartCrusher

The biggest positive environmental impact can be achieved by **CO2 free cement**. A potential technology is to extract the cement from old concrete.

SmartCrusher is an innovative technology from Netherlands that "liberates" cement from old concrete; this cement can be used for new high-class concretes after certain treatment that is much less energy demanding than the usual cement production process; the energy for such treatment can be secured by solar panels, making the end-product (cement) completely green.

This technology requires cooperation between concrete aggregates producers and cement producers; the latter will have to change their production processes, and they need serious incentives to do so. This can only be done by regulations and policies with clear and working control mechnisms.

Smart Crusher is a cutting edge technology with great potential to reduce CO2 impact of concrete; it has several test installations, one of them in Amsterdam. Several pilot projects were already implemented with the use of cement "liberated" from old concrete by SmartCrusher.

SmartCrusher installation, NL

Here the circular concrete mixture produced by Rutte Group with the help of SmartCrusher technology is used in a reinforced concrete component that separates the road from the cycle path.
Source: slimbreker.nl, 2022

End products of SmartCrushing process

Recycling of bricks, tiles and ceramics

Bricks, tiles and ceramics can be used to produce mixed recycled aggregates that can effectively be used either for backfilling or for for non-structural construction materials, such as pavement blocks, non-load bearing wall blocks, terrazzo floors, etc

Recycling of this type of waste from demolition debris has the same challenges as for concrete: absence of crushing equipment and contamination with hazardous materials.

Mixed recycled aggregates

Samples of material called Rebetong, which is made from mixed recycled agregates
Source: skanska.cz

Recycling of metal, plastics, treated wood, and glass

Recycling of **metal** is established in UA. Scrap metal is used for high quality new metals.

Challenges:

- different types of metals have to be sorted out before recycling
- major steel producers seased operations because of the war
- heavy crushers and magnetic belts are needed to recover reinforcements from concrete

Scrap metal reinforcement recovered from crushed concrete

Most recovered **wood** is treated (painted or impregnated); treated wood and plastics (pipes, window frames) may only be used as alternative fuel (AF). AF is one of the main levers for reduction of CO2 intensity in cement manufacturing

Challenges:

Many treated wood will be burnt in regular furnaces by the population, because of energy crysis, but this way it will emitt hazardous substances.

So far cement producers are not cooperative and not interested.

Plastics in CDW

Treated wood

Plate **glass** is recycled for glass products in UA. At least one glass producer - the Kostopyl' plant - is accepting glass for recycling. Scrap glass can be used for aggregate in concrete, for production of foam glass and insulation, but these technologies don't exist yet in UA.

Challenges:

- there are very few glass recycling facilities in UA
- most of them are on the occupied territiries or destroyed
- business in this fiels is not profitable because of small quantities of this material in the demolition debris; it needs additional stimulation by legislation or subsidies

Scrap window glass collected on recycling plant RADA, Bucha region

Conclusions recycling of construction materials concrete, bricks, metal, wood, glas

Potentials

- **Amount of demolition debris offers a great potential for urban mining**. Ongoing initiatives on mapping of demolition allow to estimate quantities and point to the most potential sites for recycling plants.
- **On-site sorting and recycling with mobile equipment could decrease efforts** of logistics and CO2 emissions.
- Combustible waste (treated wood and plastics) can be used for energy recovery (for cement plants e.g).
- Concrete aggregates cleaned from hazardous materials can be used for road foundations.
- Mixed aggregates from concrete, bricks, ceramics, tiles can be used for backfilling and non-structural products like pavement elements.

Challenges

- **Debris is currently a "mission impossible"** for municipalities: No equipment, no task force, no know-how, no money.
- **No national standards for recycled aggregates** and alternative fuels, industries are not established.
- **Demolition waste contains huge amount of hazardous waste** (asbestos, PCBs, heavy metals, home appliances, medicines); little know-how in UA on how to deal with this waste, little resources and capacities; no regulations for some types of hazardous waste, (asbestos e.g.)

Recommendations

- **National program to provide know-how and financial help** for urban mining activities for municipalities.
- **Urgent need to develop strategies dealing with hazardous waste**. Financing of recycling technologies for sorting and correct storage of hazardous waste to avoid environmental collapse. **Foreign companies could help.**
- **Establish pilots** in cooperation with the construction sector in UA **to demonstrate the feasibility of urban mining activities**.
- **Create incentives** for the construction sector to invest in recycling.

Reuse of concrete panels: Overview

- Appx. 30% of elements from the mass housing panel buildings can be reused as structural elements, that is according to German experience with GDR legacy; in UA no case studies of such reuse exist so far, but there is a big interest to this, given the amount of such buildings
- Elements with highest reusability potential are slabs and internal walls
- Standard panels allow for easy to achieve reuse
- Application of panels for single-family houses was proofed feasible (panels can be cut into pieces)
- Database of available components could support scaling up
- Structural components must undergo tests and certification; preferrably such testing should happen on-site because any transportation decreases benefits of reuse;
- Reuse is preferrable close to the original site (expensive logistics due to size and weight)
- Today there is no expertise in the country for reusing concrete panels from soviet mass housing
- Potential for new markets

Source: Bellastock, La Fabrique du Clos, 2017

Reuse of concrete panels: Case study from GE

East Germany has a rich legacy of mass panel housing. During 2005 -2006 three pilot projects were realized by Conclus architects where they used panels from dismantled plattenbau buildings for new single-family houses build within short distance from the donor building.
The technology prooved reuse feasible, the cost savings were about 26% compared to a house built by traditional methods.

For the house in Mehrow (left image) the slab and wall components were supplied by a donor building 8 km away. Demounting, processing and remounting took place "just in time," within 12 days. The façade was covered with an external thermal insulation composite system (ETIC). Altogether, 118m³ of prefabricated concrete units reused.

Quality of the Ukrianian panel housing varies considerably from series to series. Even if the feasibility was prooved for German P20 series in Ukraine we will need to do studies and laboratory tests for different houing series.

project: Mehrow House, Mehrow, Berlin; arch. Conclus, Berlin—Hervé Biele., 2005

Reuse of steel structural components in EU and UA

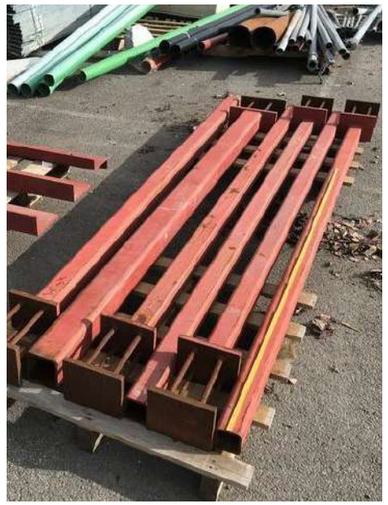
Reuse of structural steel has high environmental potential, because steel recycling is an energy demanding process that usually involves fossil fuels. Transition to "green steel" production where hydrogen is used instead of fossil fuels is still the future.

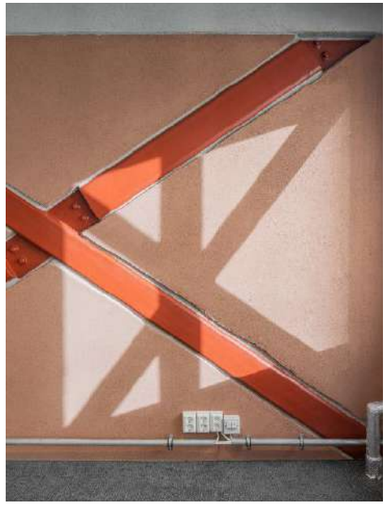
Reuse of structural steel for new structures is limited by regulations that require certification and structural test for reused elements.

The reuse of structural steel was prooved feasible with several implemented projects in UA and worldwide.

In UA most buildings with steel frames are industrial buildings.

KA13 project by Mad.no in Oslo is a building made of 80% of reused materials, including steel for load-bearing structure. This case was interesting because steel beams came from different sites and had a varying length; for some of the metal beams additions were made to extend their length. This illustrates how challenges in reuse can be overcome by design and innovaion.





mad.no, KA13, Oslo

Salon BMW built by Drozdov&Partners company in Kharkiv in 2015 has steel framework reused from an industrial building nearby.

Drozdov&Partners, salon BMW, Kharkiv

Reuse of bricks: Examples from DK and UA

Reuse of old bricks is already done in UA; most secondary bricks on the market were produced until 1970s, after that strong cement based mortars became popular; cleaning of cement based morters from bricks is more time and resource consuming operation than cleaning the loose lime mortar. Moreover, older bricks in UA usually have higher quality and better visual charcteristics.

Reuse of bricks in UA is established for DIY construction; but it was also realized in several big-scale projects by Drozdov&Partners, Kharkiv-Lviv and MetaLab, Iv-Frankivsk.

Resource Rows project by Lendager Group implements an innovative approach to bricks reuse: in fact, brick walls of old buildings were cut into pieces and reused as bigger blocks for new load-bearing walls.

Resource Rows by Lendager Group, Copenhagen

The most well known example of reuse of old bricks for new facades in UA was done by Drozdov&Partners company for the public building in Kyiv - Theatre na Podoli. Old bricks perform the design function here - they make the new building blend into the historical setting of old Kyiv.

Theatre na Podoli, Drozdov&Partners, Kyiv

Reuse of different materials: Creative approach

For this refurbishment project the reclaimed wooden planks were cut into sets of fixed lengths, but the width could vary. As a consequence, a variety of planks of different sizes could be used for the cladding, whilst still ensuring a certain regularity, and hence a certain ease of installation. Moreover, by including short standard lengths in the overall composition, the design allowed for the integration of offcuts and shorter planks, further reducing waste.

Creative wooden facade from reclaimed wood
The Botanical Institute building of the University of Liège

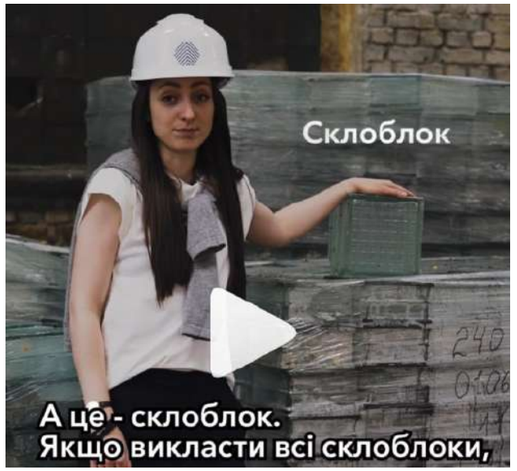
Yet another variation of the same principle: intact ceramic tiles are used to define a geometric grid, in which broken tile pieces can be placed in an opus incertum pattern.

Reuse requires a creative approach and good will; in UA we still have "suspecious" and superior attitude towards secondary products; but interest in circular design is growing especially among the younger generation of architects.

Creative tiles reuse, NL

The MetaLab company in Ivano-Frankivsk is one of the few architectural companies in UA that does reclaimation and integration of secondary materials.

In PromPrylad renovation project they reclaimed huge amount of glass blocks which they intend to use for refurbishment on the same site.



Glass-blocks prepared for reuse, MetaLab, Ivano-Frankivsk 2022

Reuse of windows: Examples from EU

Windows and plate glass is one of the most scarce materials in UA now. The reason is that windows suffer most from the explosions. The other reason is that two large producers of window glass (Kostiantynivskiy and Lysychanskiy zavod) remain under occupation.

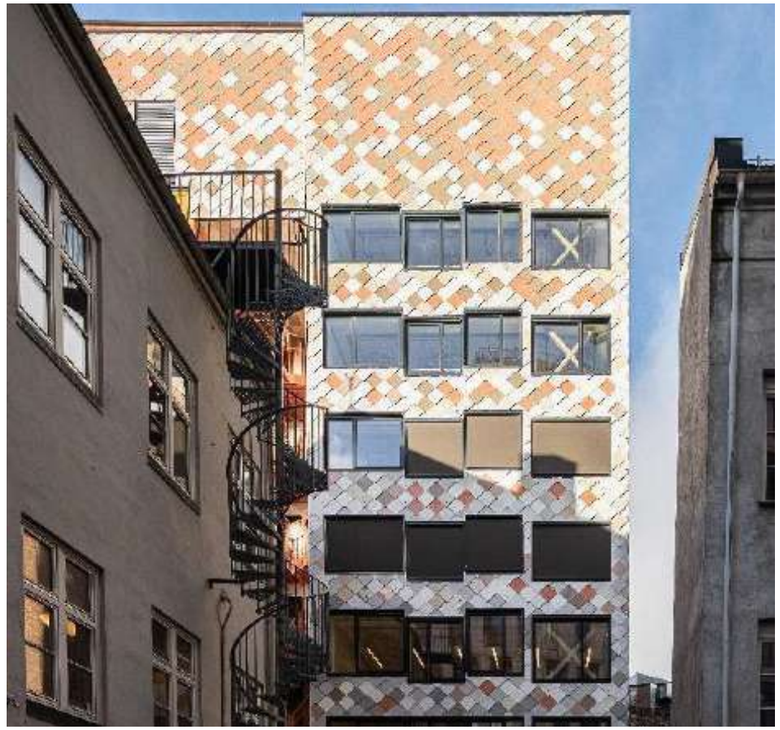
Recycling of plate glass is an energy consuming process therefore reuse has huge environmental benefit.

Reuse of windows has two main challenges:

- windows reclaimed from different buildings usually have different dimentions and integrating them into a new building requires creative design approach;
- old windows usually don't comply with the current energy-efficiency regulations.

At the moment there is a number of initiatives that transport (or have plans to do so) reclaimed windows from Poland, Switzerland, Denmark to Ukraine to cover the urgent need. But according to one of the volunteers involved, such windows are not very popular - people have difficulties to integrate windows with certain dimentions into existing openings that have other dimentions.

There is a number of projects in EU that integrate reclaimed windows of different dimentions into one building, prooveing that this is just a design task.



KA13 project by Mad.no, Oslo, 2019

Poor energy-efficiency of reclaimed windows is also challenge that can be overcome by design. In the Upcycle Studios project by Lendager Group they put the windows in two layers, thus achieving perfect insulation.

Upcycle Studios by Lendager Group, DK, 2020

Conclusions reuse of building components in UA

Reuse is established in the construction of single-family houses in UA. Bigger scale pilot projects are realized in the EU.

Potentials

- **Price for reused elements is very low**
- Reuse, logistics and polishing **could create many jobs and a new market** in UA.
- Design with reused components is a creative task and **can increase the part of intellectual services in the construction sector** (today very low)
- Reuse of steel frames, concrete elements and windows offer most potential for circularity

Challenges

- **Know-how to design** with secondary elements **is low**. Very few big-scale pilot projects with reuse were implemented in UA and mainly with bricks.
- **Absence of standards and procedures for certification of reused structural elements**
- Municipalities have **no financial incentives for reuse**: Dismantling for reuse makes demolition more laborous, expensive and adds administrative work
- The **'bad image' of secondary materials**; knowledge about benefits and opportunities is very limited

Recommendations

- Introduction of a **bonus system for state-supported demolition measures** considering environmentally relevant aspects to provide incentives for municipalities and private companies.
- **Online directory of building elements and storage sites** like Opalis.eu, Salvoweb.com in EU can facilitate the process in UA
- **Reclaimation audit procedures**, **manuals and training courses** can help to prepare specialists in reclaimation of building elements.
- **Initiate pilot projects to show that large scale construction by reusing building elements is feasible.**

CIRCULAR CONSTRUCTION METHODS USING RESOURCES IN UKRAINE

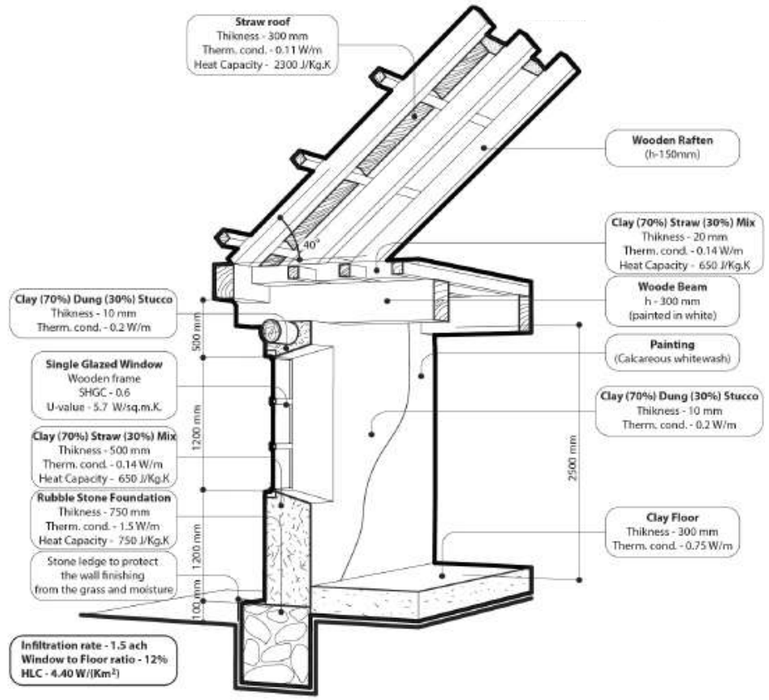
Traditional building techniques

- Clay, straw and wood are the most common and locally available construction materials in UA
- Traditional building technique for Mazanka (ukrainian country house): Walls made of a frame, limestone or raw bricks, coated with clay. Raw brick is briquetted by a mixture of clay and straw and dried in the sun.
- A big part of the actual housing stock in rural areas are Mazankas
- The construction technique is still used in rural areas, but the image of Mazankas is rather low: (poorness and an old-fashioned life style with small windows, small rooms, low technical standards)

> **introduce examples of modern stray and wood construction**

> **provide know how for modern techniques**

Typical Mazanka

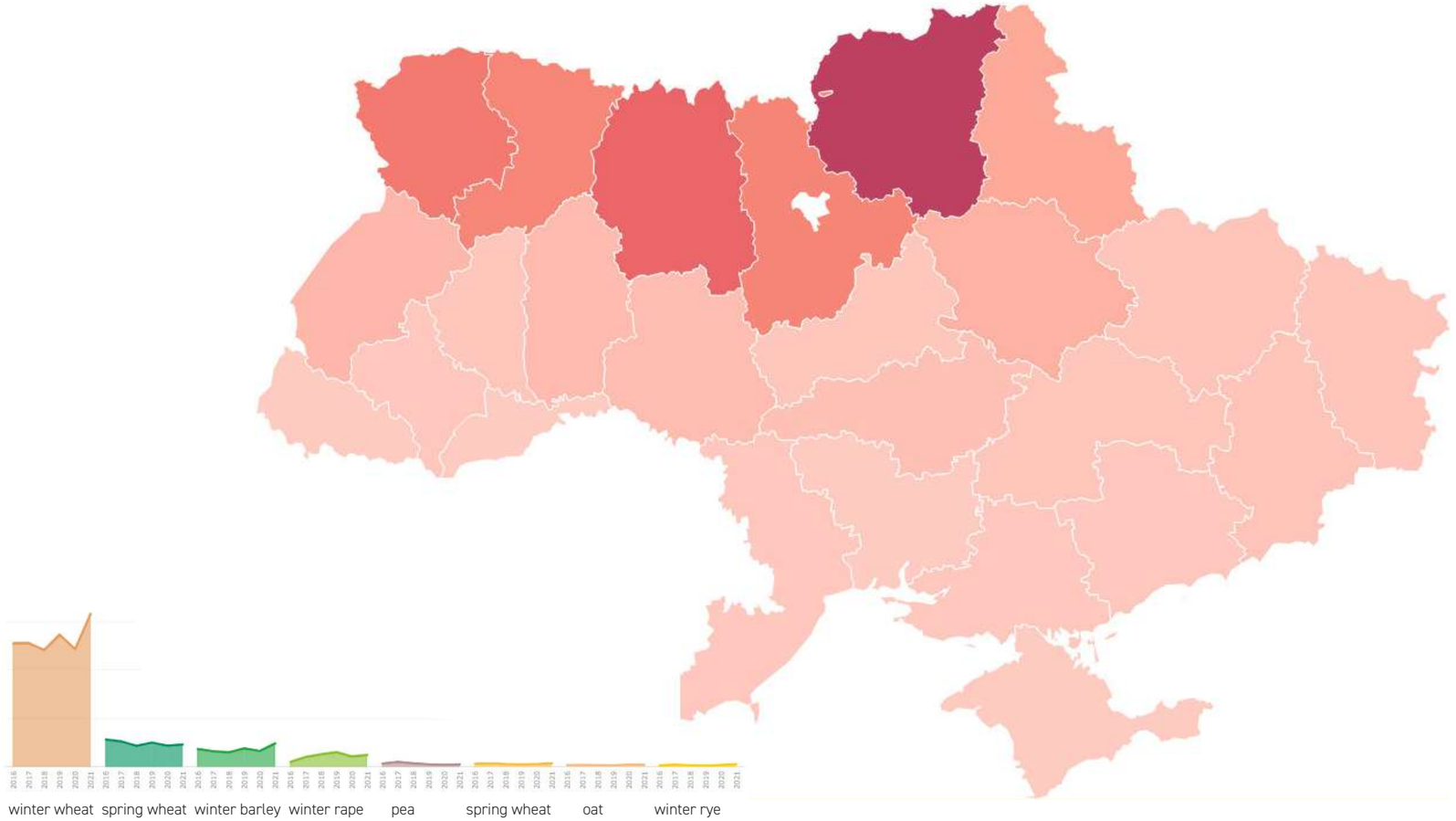


Artem Oslamovskyi: Typical construction scheme of a Mazanka

Rye straw

- renewable resource, rye straw best suited for construction: Contains a tiny amount of nutrients and keeps insects and rodents away
- Rye is mostly grown in Chernyhiv obl and Polissija region
- Compared to other crops rye is grown much less
- In 2021 - 616 thousands tons of rye were produced. With coeff. 1.3 > 800 thousand tons of straw a year
- Today most of straw is down-cycled: burnt for energy recovery, used for anial bedding or food, mulching, etc
- In 2022 rye was not grown at all because of low profitability
- At the same time until 2022 rye was not allowed for export, in 2022 the ban was lifted

> **If rye straw becomes a valuable construction material, the profitablility to grow rye will increase fast**



Map: Rye crops distribution in Ukraine
Chart: Rye production compared to other crops
Source: https://public.tableau.com/ map created by MUKOVOZ.DESIGN

Straw-clay-wood prefabrication: Technology

- Very good insulation: 40 cm facadepanels reduce heating and cooling up to 80% compared to standard walls
- Wood-straw panels plastered with clay have fireresistance class REI 60
- Exceptional sound insulation 56 Db (40 cm facadepanels)
- Space requirements for production plant: approx. 1200 sqm covered production space, approx 250 sqm storage
- Production doesn't require expensive equipment
- Prefabrication allows for fast construction and decreases materials usage
- Current legislation: Wooden frame construction allowed up to 3 stories, more with concret or metal frame construction
-

> **straw-clay-wooden prefabricated panels have great potential in UA to become availbale as non-load bearing wall material as alternative to standard insulation materials (foam concrete, mineral wool, foam plastics, etc.)**

Panels and houses produced by Life House Building Company
Source: https://www.instagram.com/life.house.building

Prefabrication with straw-clay-wood: Market overview

- A number of companies is using this technology in UA;
- More than 100 single family houses realized in UA during the last decade;
- There is one ongoing project for 15 apartments in two-story buildings, the project was designed by Life House Building company; it is paused because of the war;

Single family house of straw panels, Lviv, 2021
private, Life House Building

Design project (not implemented) for 15 apartments for IDPs, Kyiv, 2022

commissioned to Life House Building by Ministry of Defense of UA

Producers in UA:

lhb.com.ua/
ecopanel.com.ua/
eco-bud.com/
avers-agro.com.ua/
www.novator-group.com
www.soloma.house/

Straw, clay, concrete: Case study

Project: Soubeyran
housing cooperatives d'habitation Equilibre and Luciole
atba.ch Architects
Geneva, Switzerland - 2016

- Light concrete strcuture, facade insulation of two main facades with straw bales, interior wall cladding from earth
- energy efficiency class A + .
- Waste water is managed in a closed cycle through the production of compost produced from organic substances in the toilet facilities and reuse of waste water for toilet flushing and irrigation.
- Active involvement of residents in the project from design phase to construction
- Several meeting areas and spaces for communal use: Roof terrace with gardens, common rooms, guest rooms

Source: atba.ch

Source: atba.ch

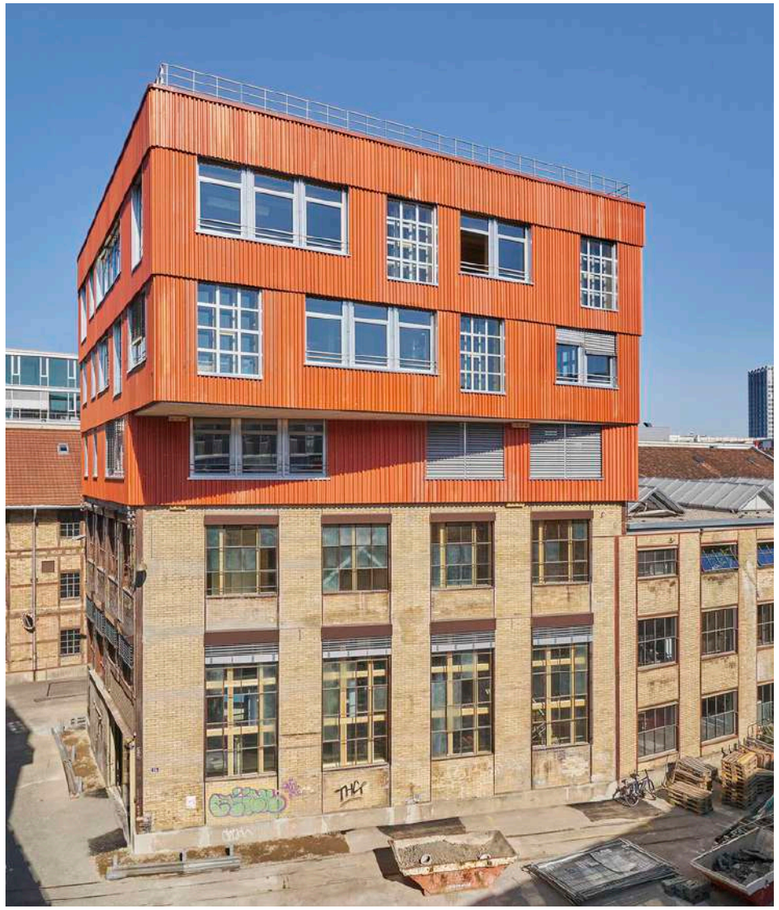
Source: atba.ch

Reused building components, straw, clay, wood: Case study

Project: K118
by bau Buro In Situ
Winterthur, Switzerland - 2021

- Renovation and extension of an existing industrial building
- energy efficiency class A + .
- The goal in this project was to reduce the embodied energy: 60% of CO2 emissions and 500 tons of primary materials were saved
- Most components and materials are reused, including structural elements
- Usage of concrete is limited to absolutely needed
- Walls made of straw panels with wooden frames allow adaptation to different sizes of reused windows coming from different sources

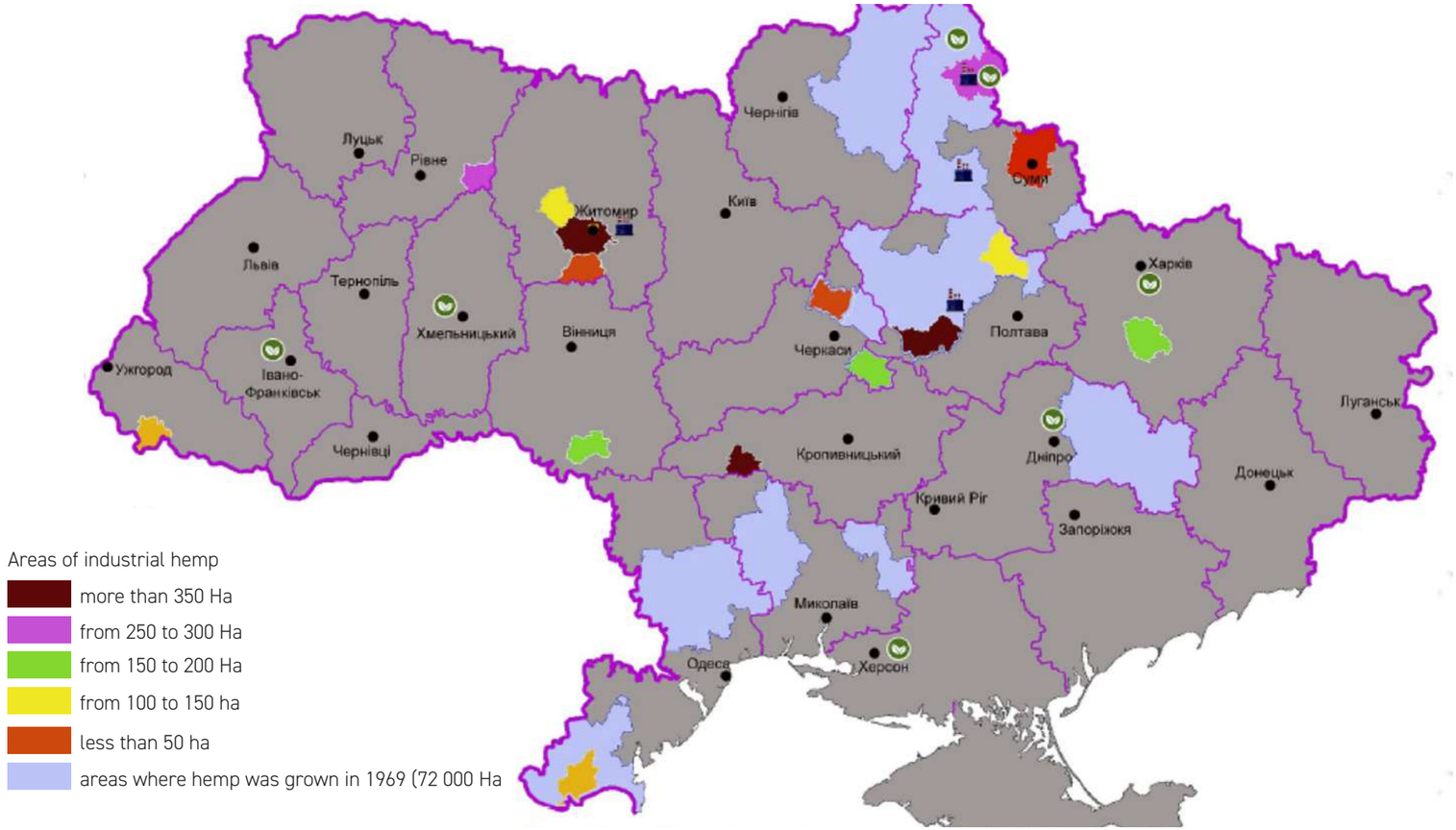
Source: Bauburo In Situ



Source: Bauburo In Situ

Availability of hemp

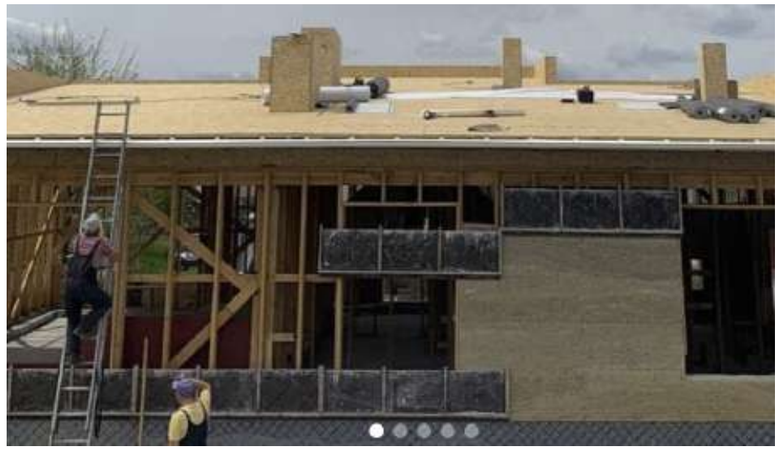
- A renewable resource and the fastest growing crop on the planet
- Hemp doesn't require fertilizers and is not demanding on water or soil
- Amount of hemp production in other countries grew considerably in recent years: this is an opportunity for UA too
- Current legislation: Technical hemp is allowed in UA, medical hemp not. Strict control procedures make the business difficult



Hempcrete: technology and UA market

- Hempcrete is an ecological insulation material made of hemp and lime
- Hempcrete provides excellent heat and sound insulation and if covered with clay plaster is fireresistant
- No special equipment is necessary for production of hempcrete
- Hempcrete is used as a wall material for wooden frame houses; wooden frame houses is an established technology in UA
- Legal regulations allow for buildings with wooden frames up to 3 stories
- Hempcrete is a fast growing trend in UA, though expertise is still limited
- The technology can be used by DIY builders as well as by SME

Producers in UA:
hempire.tech



Source: photos fro the workshop by HEMPIRE

Source: instagram of Founder & CEO of HEMPIRE

Hemp and limestone: Case study

Project: Case di Luce

Pedone Working Group Architects

Bisceglie , Italy - 2016

- Two multi-story residential and commercial near-zero-energy buildings with 61 flats
- energy efficiency class A + .
- Innovative building system was implemented called Muratura Vegetale® in Natural Beton® (mixture of hemp and lime)
- Low energy demand and almost no maintenance costs while providing excelent insulation

manufactured hemp-clay stone

raw hemp-clay mix

Source: Ing. Pietro Pedone et al 2019 IOP Conf. Ser. Mater

Conclusions construction methods with rye straw and hemp in UA

Potentials

- rye and hemp are fast growing crops, **UA is a big agricultural producer**
- Straw is burnt today for energy recovery or being downcycled
- **Rye-straw technology is popular for single-family houses in ecologic construction**
- Rye-straw panels are prefabricated, don't require complex equipment and allow for fast construction
- **Hemp and lime (so-called hempcrete) insulation material are gaining popularity** in ecologic construction
- Both **technologies used for buildings up to three floors** with wooden structural frames
- With stronger structures (concrete, engineered wood, metal) **use for higher buildings possible**.
- **Hemp and straw are relevant alternatives** to standard products **with negative carbon foortprint**

Challenges

- Hemp and rye are grown today in smaller quantities compared to other crops
- **Sector is still very small in UA**
- **Little expertise on technology in UA** (capacity building efforts needed to realize large scale reconstruction)
- Expertise in the field exists for small scale construction, not for high-rise buildings.
- Technologies make very low part of the construction sector today

Recommendations

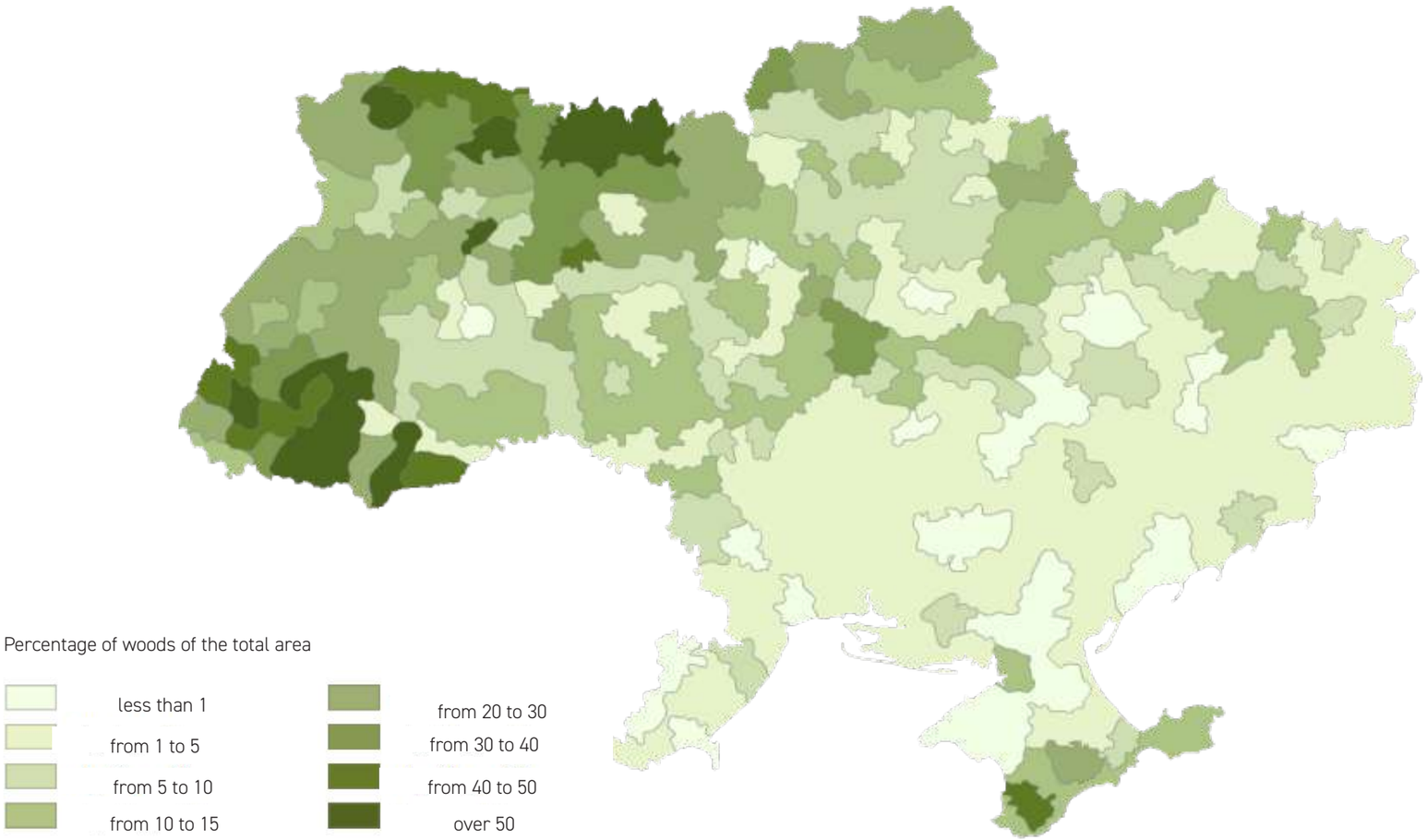
- **Know-how from foreign experts in the field** could help the existing technologies to develop and grow
- **measures to support** (subsidies, grants) and create awareness

Wood in UA: Overview

- Forest coverage of Ukraine is with 15.9% relatively low.
- Forests are very unevenly distributed and concentrated mainly in Polissia and the Ukrainian Carpathians.
- Over the past 50 years, the country's forest coverage has increased by almost 1.5 times, and the wood stock has increased by 2.5 times.
- The stock of wood in the forests is estimated at 2.1 billion cubic meters. The total average change in reserves reaches 35 million cubic meters annually
- Since the full scale invasion great percentage of UA woods were damaged
- Current energy crisis in UA causes that large quantities of wood are used for heating

Conclusion:

> **Wood is a limited and unevenly distributed resource in UA, the deficit in forest coverage existed before the war and war will make it much bigger**



Source: State agency of wooden resources of UA, 2019

Engineered timber: technology and UA market

- CLT panels and gluelam beams provide structural qualities close to concrete
- CLT panels are produced in UA, no gluelam products
- Much interest on this technology in the building sector but little practical expertise (single-family houses implemented)
- No national standards for engineered wood
- engineered timber construction is more expensive than standard technologies like concrete

Source: private practice of Andrii Bidakov, engineer, expert in wooden constructions

CLT modules have been produced on the plant in Korosten', Zhytomyr obl

Producers in UA:

"Ukrainian Holding Sawmill Company" in Korosten, Zhytomyr obl: rezult.pro

Modular construction with CLT: Case study

Project: Juf Nienke
by SeARCH & RAU
Amsterdam, NL - ongoing

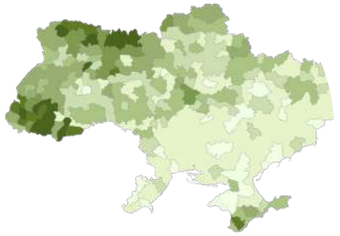
- 61 rental appartments
- 15m high CLT structure on top of a concrete platform
- utilizing recycled materials
- Prefabricated modules allow minimum construction time
- Paired or stacked to create a larger house with private exterior space for each appartment
- modules with standard width of 4m, varying depths
- Facilitation of a future dismantling and reuse
- Up to 580,000 kg of CO2 storage because almost entirely of wood
- Modules offers great flexibility, allowing to be easily dismantled, moved, enlarged and expanded
- Spatial modules allow for a good structural stability (relevant for UA because of war threat)

Source: SeARCH architects

Source: SeARCH architects

Source: SeARCH architects

Conclusions construction methods with wood in UA



Potentials

- Engineered **wood** for constructive structure **provides a carbon negative** alternative to constructive concrete structures
- Design for future **adaptability and** for **disassembly could create long term circles of usage**

Challenges

- **Availability of engineered wood in UA is limited** by high price; lack of expertise; lack of national standards
- **Availability of wood as a material is limited in UA** and will be even smaller in future because of its intensive use for heating due to the actual power cuts in UA

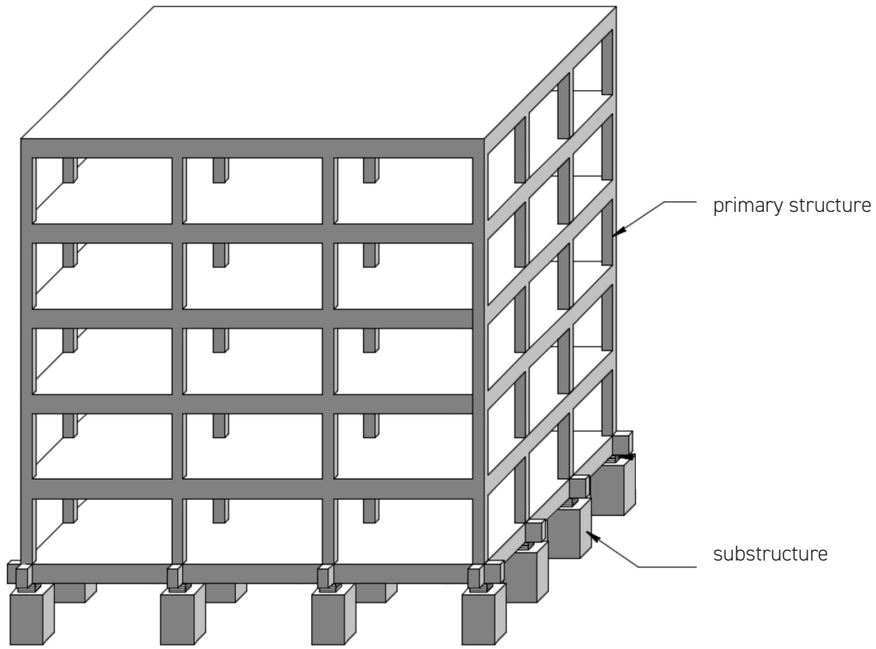
Recommendations

- **Use of engineered wood for building structures** which (=most long-lasting building layer)
- Design **structures for maximum adaptability and future disassembly** to ensure maximization of life-cycle
- Prefer use of spatial modules from CLT for better structural stability and high resource efficiency.

Circular construction technologies with concrete

Concrete is the most popular structural material for buildings, while circular concrete cannot be used for structural elements on wide scale because of its technical limitations. Therefore, the general approach to concrete is to limit it's usage to where it cannot be avioded and to reduce its quantities. Main approaches for using concrete in a circular way are:

1. Design building structures for maximum adaptability and longevity: this means that floor hights and floor loads must allow for change of function (from residential to production or commerce and vice versa) and for flexible floor plans;
2. Prefabricated concrete elements allow for disassembly and future reuse; prefabrication can save 20 - 40 % of material in the constructruction phase.
3. Design hybrid and light-weight structures that minimize usage of concrete (see case study 'Kreislauf-Wohnhaus')



Building structure is the most long-lasting part and is usually built with concrete; it must be designed for maximum longevity and adaptability

Concrete primary structure case study NEST

Project: NEST
by EMPA
Zurich, Switzerland - 2016 - ongoing

- NEST project is a cooperation between research laboratory, industry and public investors
- This is a perfect example of highly adaptable structure from concrete: all other non-structural layers of the building can be replaced if needed without changing the structure itself
- NEST is home to a wide range of innovations in the construction sector
- NEST has a primary concrete structure; modules are added in between and can be replaced
- Though NEST is a research project, tests for the use of living with temporary residents

Installing a prefabricated module onto the concrete structure
Source: EMPA

NEST building
Source: EMPA youtube channel

Concrete and light metal structure case study

Project: Kreislauf-Wohnhaus
by Troxler Architects
Zurich- 2021

- Each material is used according to its best properties and only where it can create the most impact to resource efficient and carbon neutral construction
- Primary components made of steel, concrete and wood: Concrete used for the basement, concrete and wood for upper floors
- Steel was not used as a light supporting structure in combination with composite sheet metal ceilings. Sheets served as lost formwork for the concrete
- Wooden elements used to reduce the wall thickness
  The rigidity of steel enforcement enables long window parapets without an additional substructure

Source: Troxler Architects

Source: Troxler Architects

Conclusions concrete as building material

Use of concrete should be minimized and limited to applications where it is not possible to avoid it, mostly to structural components

Current technologies for recycled concrete cannot provide recycled concrete of a equal structural quality as 'standard' without increase in cement proportion.

Potentials

- **Circular design approaches and prefabrication can decrease amount of concrete** used in the future.
- **Expertise in prefabricated construction** in UA
- The high amount of **debris is a new resource for recycled concrete**.

Challenges

- **Concrete industry is well established** in UA and; concrete and cement production is not limited by CO2 quotes or other measures.
- The **awareness of environmental impact of concrete is low**; concrete is the most popular and trusted construction material.
- Systems for **prefabricated concrete elements are outdated** by their architectural characteristics and energy-efficiency paramenters.

Recommendations

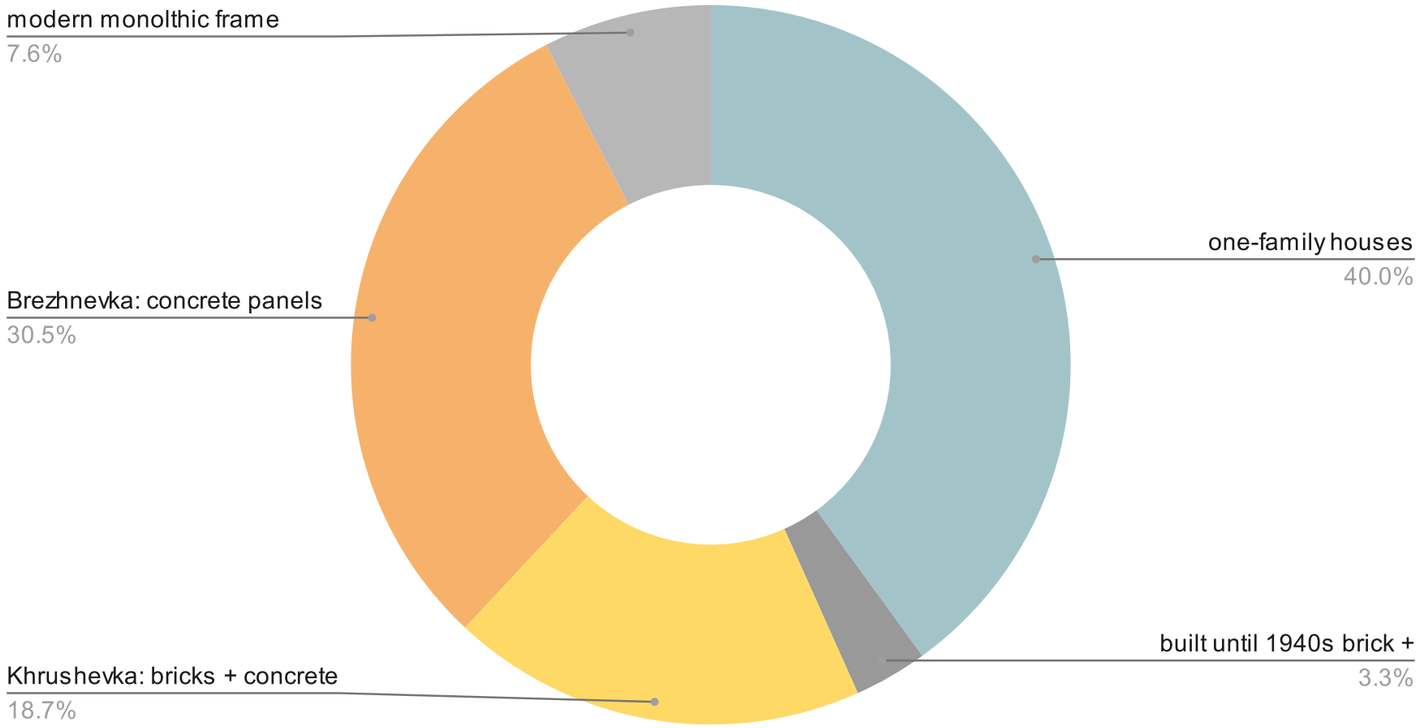
- **Recycled concrete for non-structural materials** (wall blocks, pavements)
- **'standard' concrete for structural elements.**
- **To decease concrete** used in buildings there are three main approaches:
  1) prefabrication
  2) design for adaptability and longevity
  3) combination of concrete with other materials such as engineered wood and metal

Renovation of buildings applying circular construction technologies

Types of housing by number of households

There is no statistics about types of housing in UA; but there is statistics about number of households by period of house construction.
Knowing which types of housing were built during different time periods, and knowing the fact that 40% of all households live in single-family houses the following diagram was created. While it may contain some inaccuracy, the general proportions seem to be true.

It shows that about 50% of all households in UA live in soviet mass housing buildings. This makes this type of housing



Percentage of households in UA that live in different types of housing, 2022

Generations of soviet mass housing

Khrushchevkas are 4-5-story panel and brick buildings, with external load bearing walls. Some series were planned as temporary solution for 25-60 years and now they are close to their end-of-life (mostly because of the metal connectors between panels that became rusty with time).

Advantages of Khrushevka:

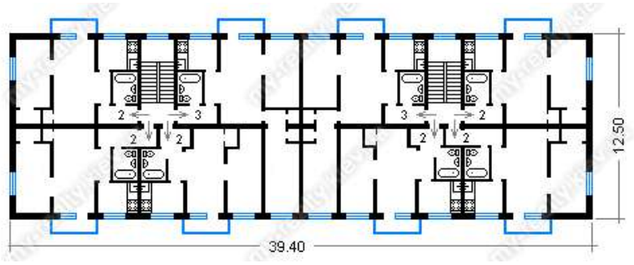
- Their small height of 5 floors created human-scale neighbourhoods which are lively, green and attractive

Approaches to renovation of Khrushevkas:

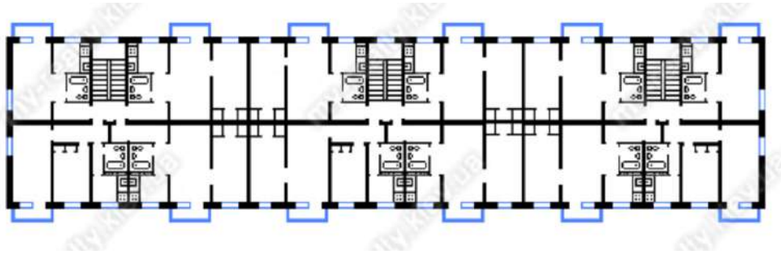
- improvement of thermal insulation, high-quality glazing;
- replanning;
- adding elevators
- strengthening of fundaments

Before the war, the national strategy in UA was to demolish Khrushevkas and to build new housing.

The reasons why Khrushevkas were not renovated massively until now are political and social: according to the Law on renovation from 2005 100% of all residents have to agree to renovation and this never happened. An alternative law was discussed lately that would decrease this percentage to 75%



1-438 built 1956 - 1964



1-464A built 1962 - end of 1960s

Generations of soviet mass housing

In 1969 a soviet directive on mass housing demanded to imrove the quality of mass housing; it required higher buildings and improved floor plans. That is how “Brezhnevka” - a 9-16-story panel building with load bearing internal and external walls appeared.

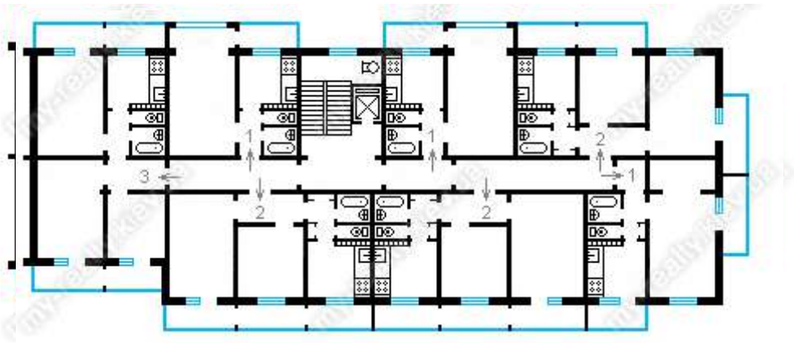
Advantages of brezhnevka compared to Khrushevka:

- elevators
- bigger area of apartments and floor heightsSeparate
- bathroom and toilet with waterproofing
- wider stairwells and flights
- the rooms are mostly isolated
- medium-sized kitchens (about 9 m)

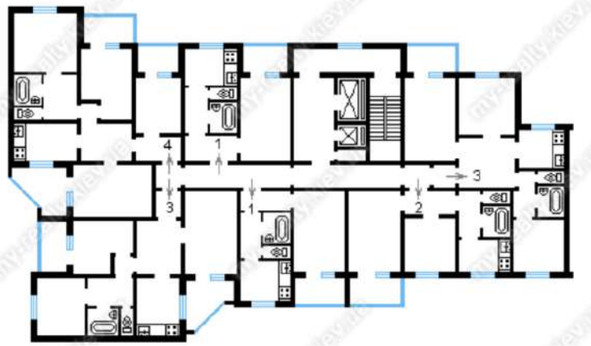
Problems of Brezhnevka:

- seams between the panels often diverge
- few options to change floorplans, most walls are load-bearing
- small bathrooms
- poor energy efficiency

Renovation approaches for Brezhnevka are similar to these for Khrushevka, with focus on heat and sound insulation and renovation of engineering systems.



1-KG-480 built 1956 - 1964



APPS-K-134 built 1986 - 2005

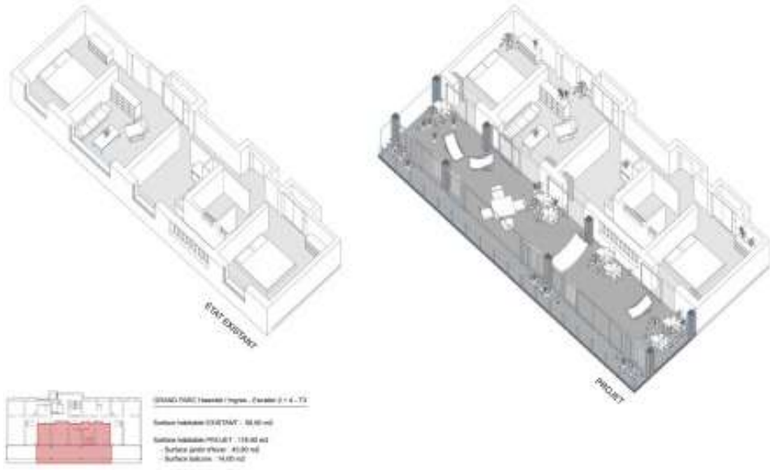
Renovation of mass housing: Case study France

Project:
by Lacaton and Vassal
Bordeaux, France - 2016

- Addition of a second layer in front the existing facade offers extra living space and works as buffering climate-zone
- Use of cheap construction elements (polycarbonate panels) enable more living space for low costs
- Change of the original architectural expression and the livestyle in the building
- Applicable to buildings with low depth (natural light capture)

New facade. Soucre: Lacanton Vassal

New additional space in added layer. Soucre: Lacanton Vassal



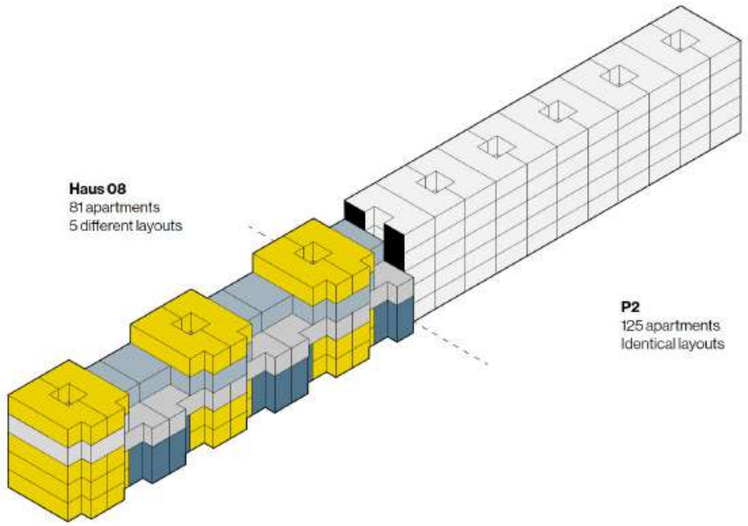
Axonometric drawing Soucre: Lacanton Vassal

Renovation of mass housing: Case study east Germany

Project: Haus 08
by Stefan Forster Architekten Halle
Neustadt, Germany - 2010

- Attempt to change the actual architecture and the experience of living in the building
- Partially removed panels to create dynamic spaces. Adding of balconies providing more space
- Conversion of apartments from identical two bedroom spaces to one of five new sizes and shapes. New variation attracts different demographics of people
- Improved energy efficiency
- Approach has been tested in this project, regarded as feasible, but too expensive to become popular.

Haus 08, Halle Neustadt 2005
Source: Tristan Bergmeuser Master Thisis



Conclusions renovation of mass housing applying circular construction technologies

Roughly half of the households in UA live in soviet era mass housing. Buildings and neighbourhoods are a identity. Preserving them means preserving social connections between residents

Most implemented renovations of mass housing in EU focus on energy efficiency and improvement of living standards; architectural quality is not in focus. Different series of mass housing need different approaches for renovation.

Potentials

- The extensive destruction and need for housing create a **momentum for innovation** in developing new mechanisms for renovation.
- **Big amount of standardized mass housing allows for systemic solutions**.

Challenges

- **Safety**: When a projectile hits buildings from the soviet era, there is an “avalanche” type of destruction.
- **Maintenance and renovation**: metal connectors are rusty, low energy efficiency and low acoustic qualities.
- Todays regulations on **ownership** (all residents are owners of appartents) create **organisatory challenges** to organize capital renovation: 100% owners must agree (according to the current law) and this never happens (many residents cannot afford renovation). New law was planned, but yet not accepted

Recommendations

- Create **mechanisms for subsidies to enable agreement** of owners for renovation in addition to OSBB.
- **Develop scalable commercial projects** to demonstrate viability of renovation.

Renovation of rural housing stock in UA

- According to national statictics (source: SSSU, 2017) from 1990 to 2017 about 3.8 mio people moved from countryside to cities; this process resulted in large numbers of abandoned rural houses;
- these abandoned rural houses, are in big part the so-called “soviet rural houses” built during 1950-1980s
- revitalization of houses would effect the revitalization of countryside
- buildings can be refitted by using traditional materials and with little construction skills
- the countryside in Ukraine today is not well developed: poor transportation, poor public and service-infrastructure, low living standards, absence of business sector.
- renovation of rural houses offers big potential for IDPs and the process has already started, but statistics is not yet available

Typical Mazanka

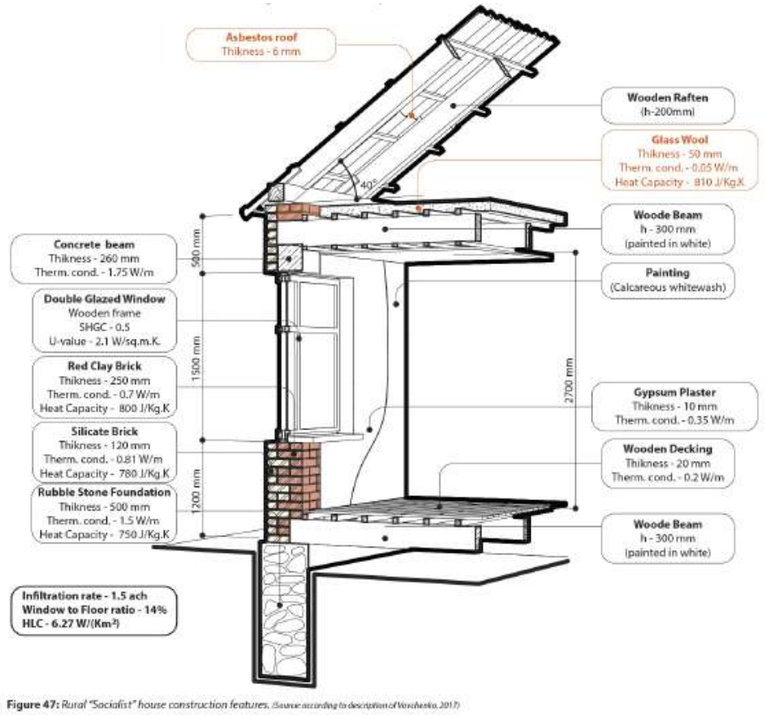


Figure 47: *Rural “Socialist” house construction features. (Source according to description of Verschenko, 2017)*

Artem Oslamovskyi: Possibilities to renovate a Mazanka

Conclusions renovation of rural housing applying circular construction technologies

Potentials

- Large amount of abandoned houses can be renovated, adapoted and enlarged exist.
- The simple construction of buildings together with their small scale make DIY- construction easy.
- IDPs moving to safer regions buying abandoned rural houses can stimulate the process and revitalize the countryside.

Challenges

- Little access to infrastructure and working places in rural areas.

Recommendations

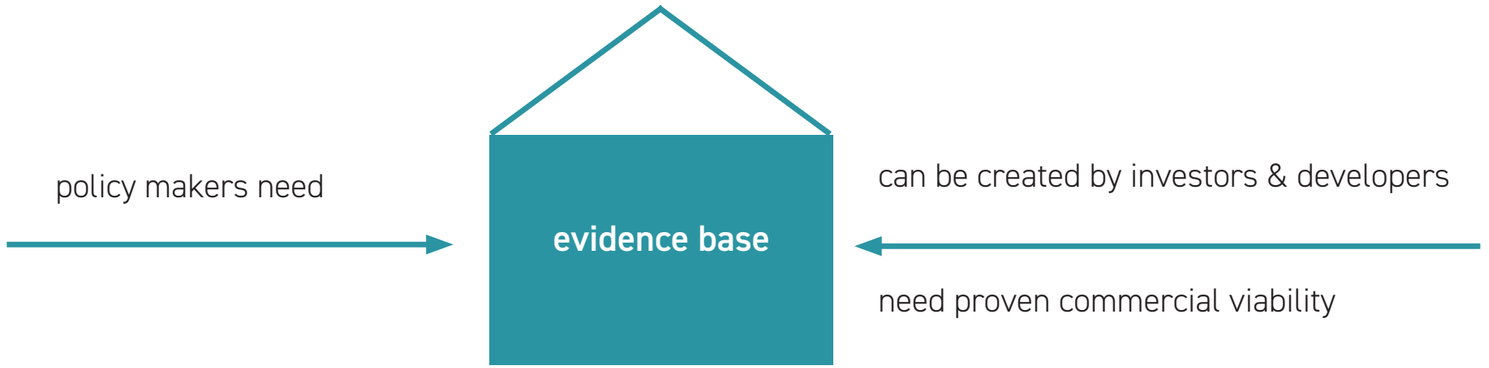
- National investments on infrastructure in rural areas: Roads, internet, public services etc.
- Regulation of ownership rights. New tenants get (possibly temporary) ownership and do renovation e.g.
- National support (know-how) and subsidies (money or materials) for renovation.

Strategic recommendations

Key stakeholders driving circular transition

Key stakeholders who are **driving the transition to circular economy** in the construction sector are*

1. **investors (both private and public)**
2. **developers**
3. **policymakers on all levels**



* according to Ellen MacArthur foundation and ARUP

Construction sector in Ukraine today

According to Derzhstat (state statistics agency in UA) **Ukrainian construction market is dominated by small and middle enterprises (SME's)**.

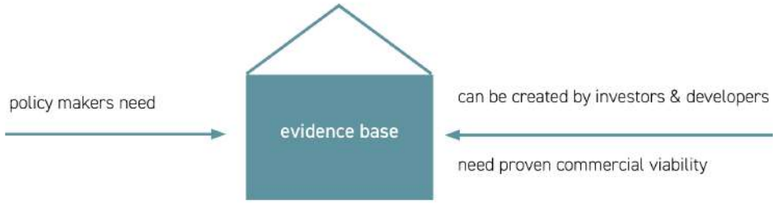
Big enterprises are responsible for 4% of sales volume in the area of construction of residential and non-residential buildings.

Before the war sales volume was growing (more than tripled since 2010), the proportions between actors of different size remained.

SME's are more flexible to change their business models and to adopt new technologies.

SME enterprises could drive the lead in transition to circularity. A supportive legislative environment is needed. **Taking the structure of the construction sector in UA, there is a big potential for a big scale shift direction circularity.**

Conclusions transition to circular construction economy



The extensive amount of demolition waste creates a momentum for big scale urban mining and recycling in the country. To make this happen, investments in infrastructure, know-how on recycling and remediation as well as new technologies are needed.

The war has created a **unique situation where the internal need for development is combined with a potential willingness of foreign investors** (public and private) to invest in pilot projects on circularity. The resulting projects can be significant internationally.

A lot of R&D is ingoing in EU. Exchange of knowhow and partnering could speed up the shift to circularity in UA and create business.

Key stakeholders that can drive the transition to circularity are investors, developers and policymakers. Policymakers need evidence base (implemented circular projects), investors and developers to create **evidence base** to make the commercial potential in it evident.

UA building industry is dominated by SME enterprises (only 4% are big enterprises); **SME are more likely to shift to circular building models**.

The involvement of local municipalities from the very beginning of a development is important: They are both, policy makers and potential investors for future housing and infrastructure projects.

Ukrainian NGOs are essential partners for initiatives because they serve as bridge to municipalities and provide knowledge of UA context to foreign partners. Currently initiatives for pilot projects around circularity arise, ro3kvit is involved in several.

Future steps

A **feasibility study for a pilot project implementing cicularity principles (from urban mining and recycling, constcution technologies, high quality design of flexible and disassemblable structures) combined with a participatory approach** involving citizens.

Potential locations: cities of **Zaporizhya, Mykolaiv, Bucha and Rivne**, because ro3kvit is already working with their municipalities in the field of strategic and master planning. In these cities **a lot of demolition took place and the need for new housing is very high**.

The feasibility study would include **finding partners and sources of financing** for actual construction; **establishing a participation process with potential residents, selection of actual plot, etc**.