Work Package 2

FutuRaM

Future availability of secondary raw materials

Future Scenarios for Secondary Raw Materials

Consortium Meeting Four – Day Two

November 23, 2023

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Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

EU Framework Programmes

Funded by the European Union

Some results from yesterdays question:

What should the scenarios answer?

- The recoverability and availability of the 6 waste streams dependent on future technologies, social impact and policy changes
- Will we be able to reach the objectives proposed by the EU? (EU green deal, CRM act, …)
- How recovery and circularity measures can enhance availability of 2RM/CRM
- Impacts of demographic change including gender, age, culture
- Content of CRM in products so these can be sorted for appropriate recovery
- How secondary supply can meet demand
- What needs to be done to enhance CRM recovery?
- The way for a better world

outside elements

sensitivity example one

Composition/volume change: Proxy for geopolitical or natural supply constraint

EXAMPLE

Reduction of a Valuable Material in the Waste Stream:

Scenario:

The model explores a situation where a previously abundant and valuable material becomes scarce in the waste stream.

Analysis:

This sensitivity analysis investigates the impact of reduced availability of this valuable material on the overall profitability of the waste management system.

Outcome:

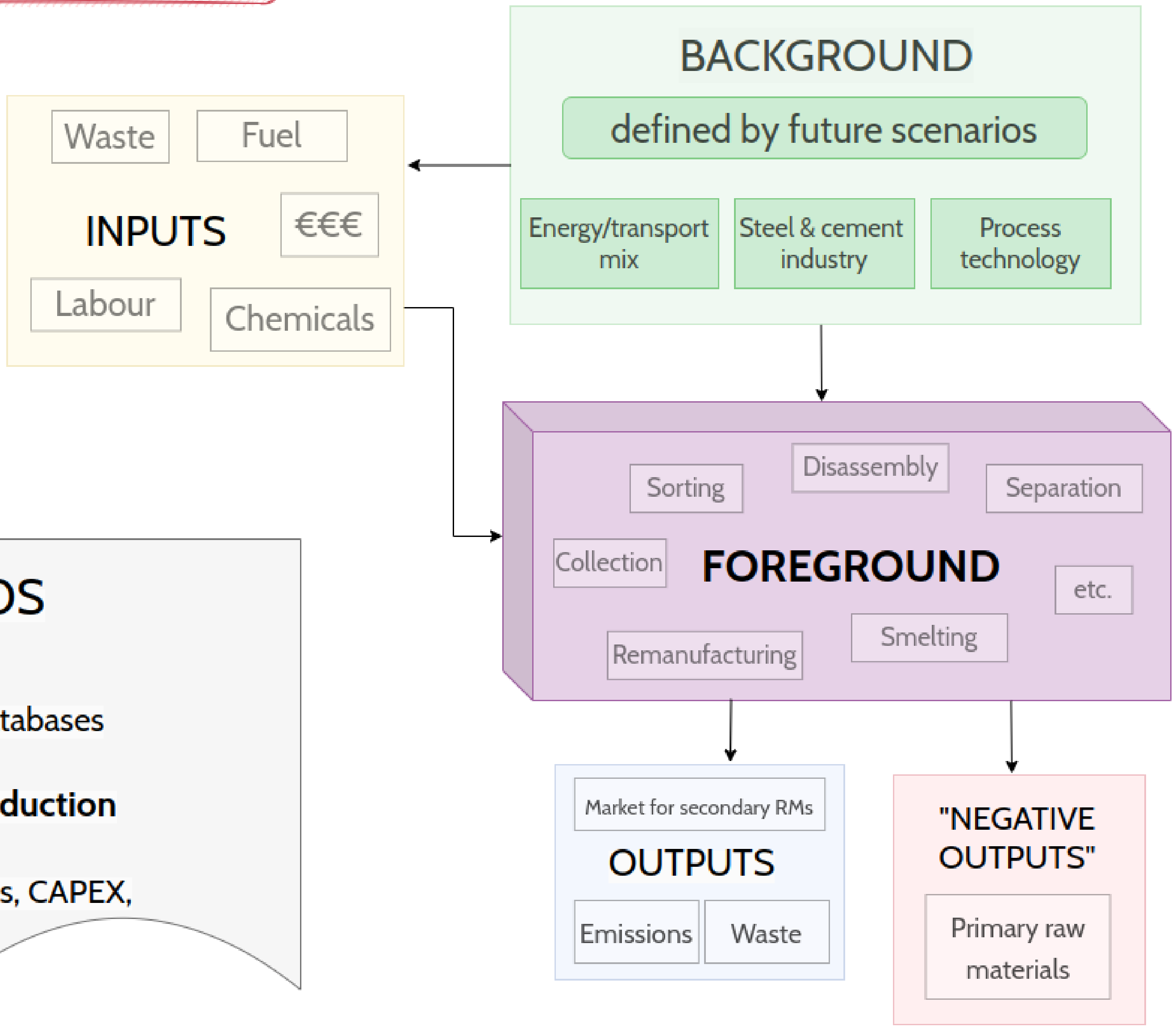
It identifies critical thresholds where a reduction in material significantly affects the system's financial viability, guiding strategies for diversifying material recovery or exploring alternative revenue sources.

2.4 - Impact Assessment Model

ex-ante life cycle assessment (p-LCA)

Recovery model:
What 2RMs can we get?
How much?

LCA model:
What else is produced and consumed?
What are the specific impacts of these?



DATA NEEDS

- **Process data**:
  from literature, LCA databases
- **Impacts of primary production**
- **For costing**: material prices, CAPEX, OPEX

WP 2 – Future Scenarios

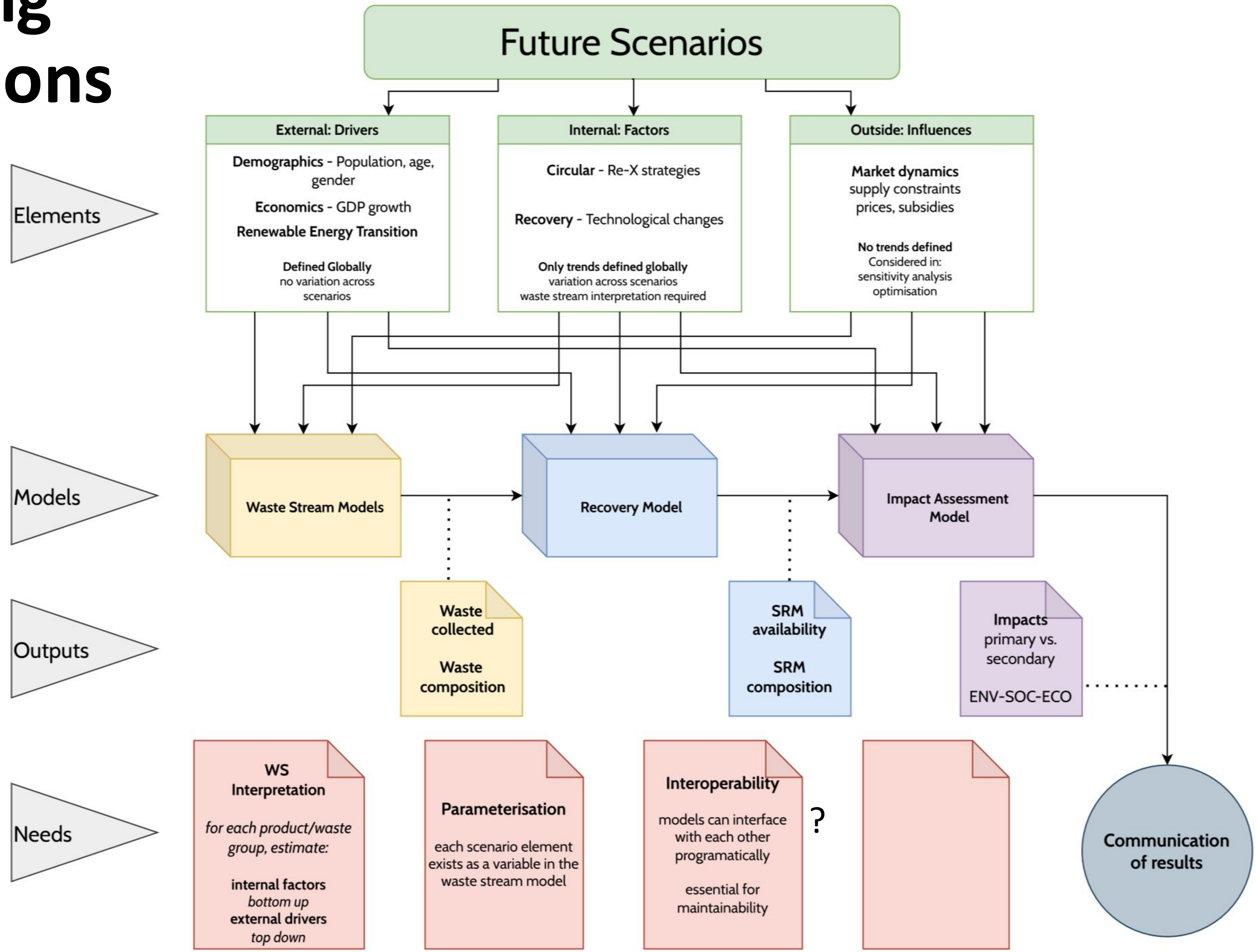
Connecting to WP3 and WP4

Discussion

Breakout to WS for scenario interpretation

Discussion

Modelling connections

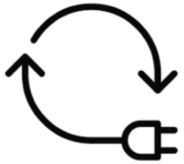


FutuRaM
Future availability of secondary raw materials

SCENARIO TRENDS

Scenario Parameter	Type	BAU		
Demography	EXTERNAL	Population stable, increase in age, urbanisation, migration		
Economy	EXTERNAL	Slow stable GDP growth,		
Renewable energy transition	EXTERNAL	Continual growth, but short of EU targets (IEA STEPs scenario)		
Product technology (composition)	INTERNAL	Current trends	Design for R4+	Design for R1+
Recovery system technology	INTERNAL	Current trends	Rapid development	Slower development
Recovery system development	INTERNAL	Current trends	Strong growth	Lower volumes
R0-3: Refuse reduce, reuse, repair	INTERNAL	Current trends		Main focus
R4-6: Remanufacture, refurbish repurpose.	INTERNAL	Current trends	Strong growth	
R7-9: Recycle, recover, remine	INTERNAL	Current trends	Main focus	Last resort

external drivers



External drivers

Scenario elements

- **Demographic change:** population, median age, urbanisation, gender
- **Economic growth:** GDP
- **Renewable energy transition:** energy mix

Waste model parameters include:

- **Put-on-market**
- **Composition**

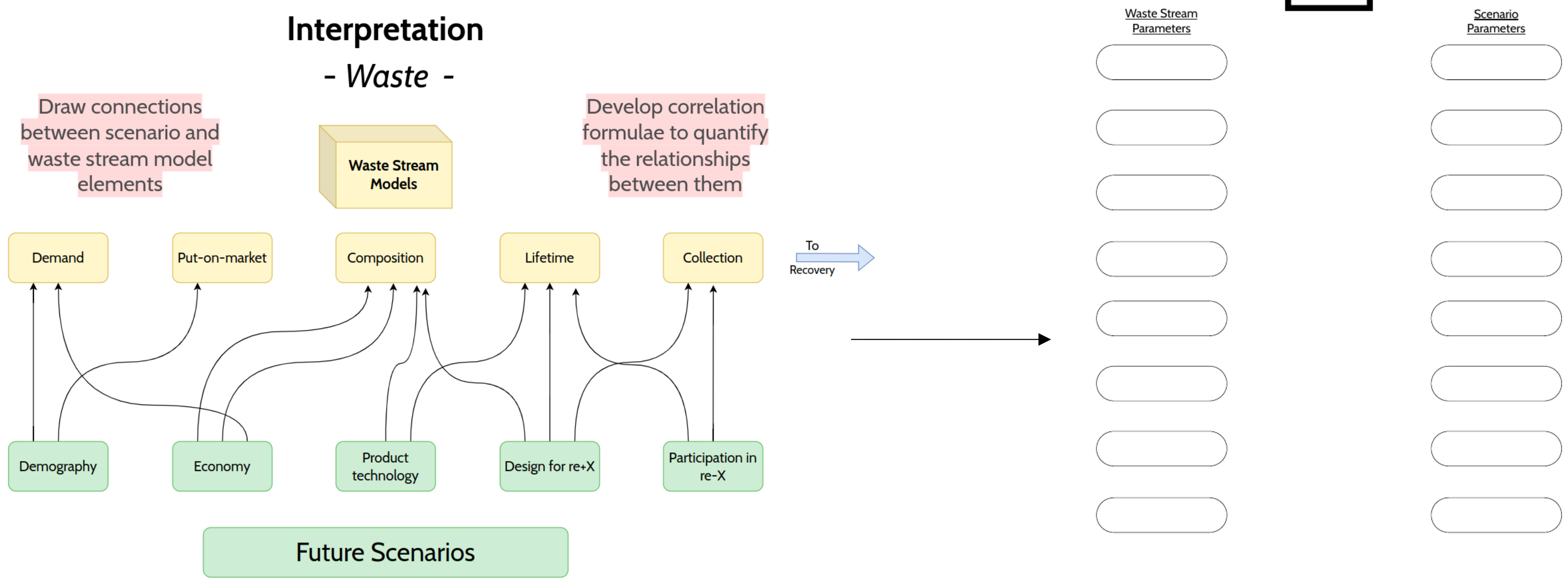
Recovery model parameters include:

- **Recovery processes:** market penetration of recovery technologies
- **Transfer coefficients:** function of recovery technologies
- **Recovery system size:** BAU - set by trends in BAU, CIR & REC - defined by model outcomes within constraints

Impact model parameters include:

- **Foreground inventory:** inputs and outputs of recovery system
- **Background inventory:** energy mix, impact of primary production

Task 1. Map out parameter relationships for your waste stream



WS parameters

Put-on-market	Put-on-market
Put-on-market	Put-on-market
Lifetime	Lifetime
Lifetime	Lifetime
Composition	Composition
Composition	Composition
Collection rate	Collection rate
Collection rate	Collection rate
Export rate	Export rate

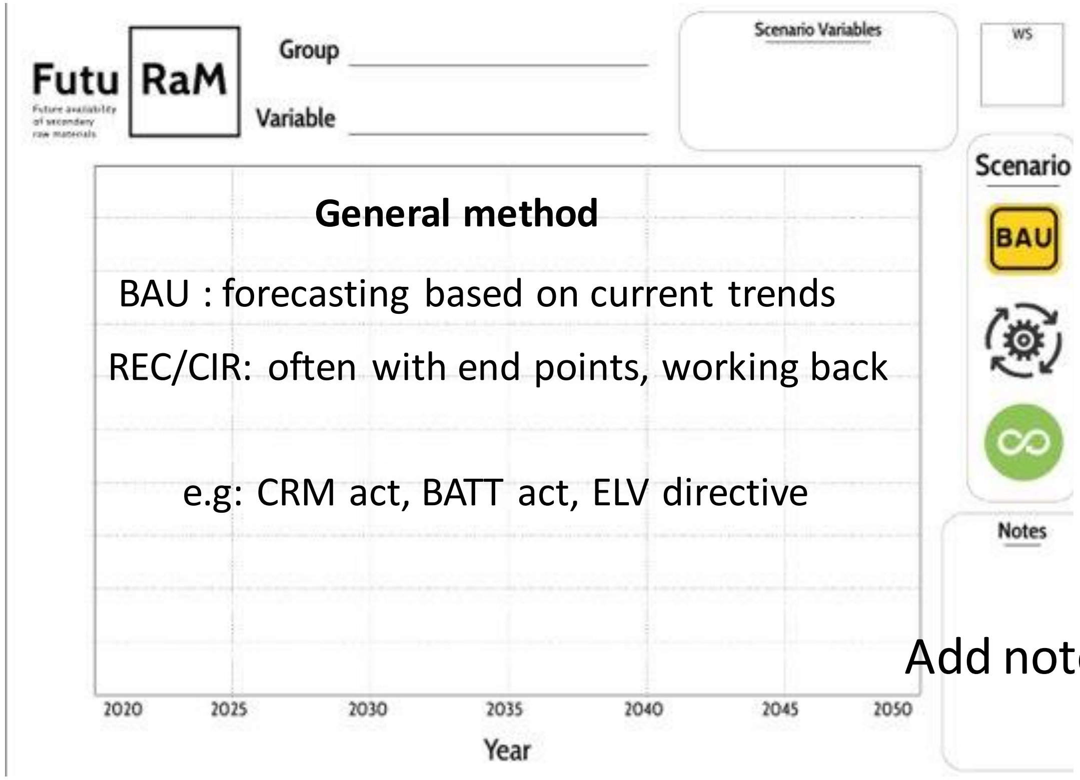
Recovery parameters

TC for -	TC for -
TC for -	TC for -
Efficiency of -	Efficiency of -
Efficiency of -	Efficiency of -

Scenario parameters

GDP growth	GDP growth
GDP growth	GDP growth
Population	Population
Population	Population

Task 2. Choose some combinations of 'product'/parameter and create figures



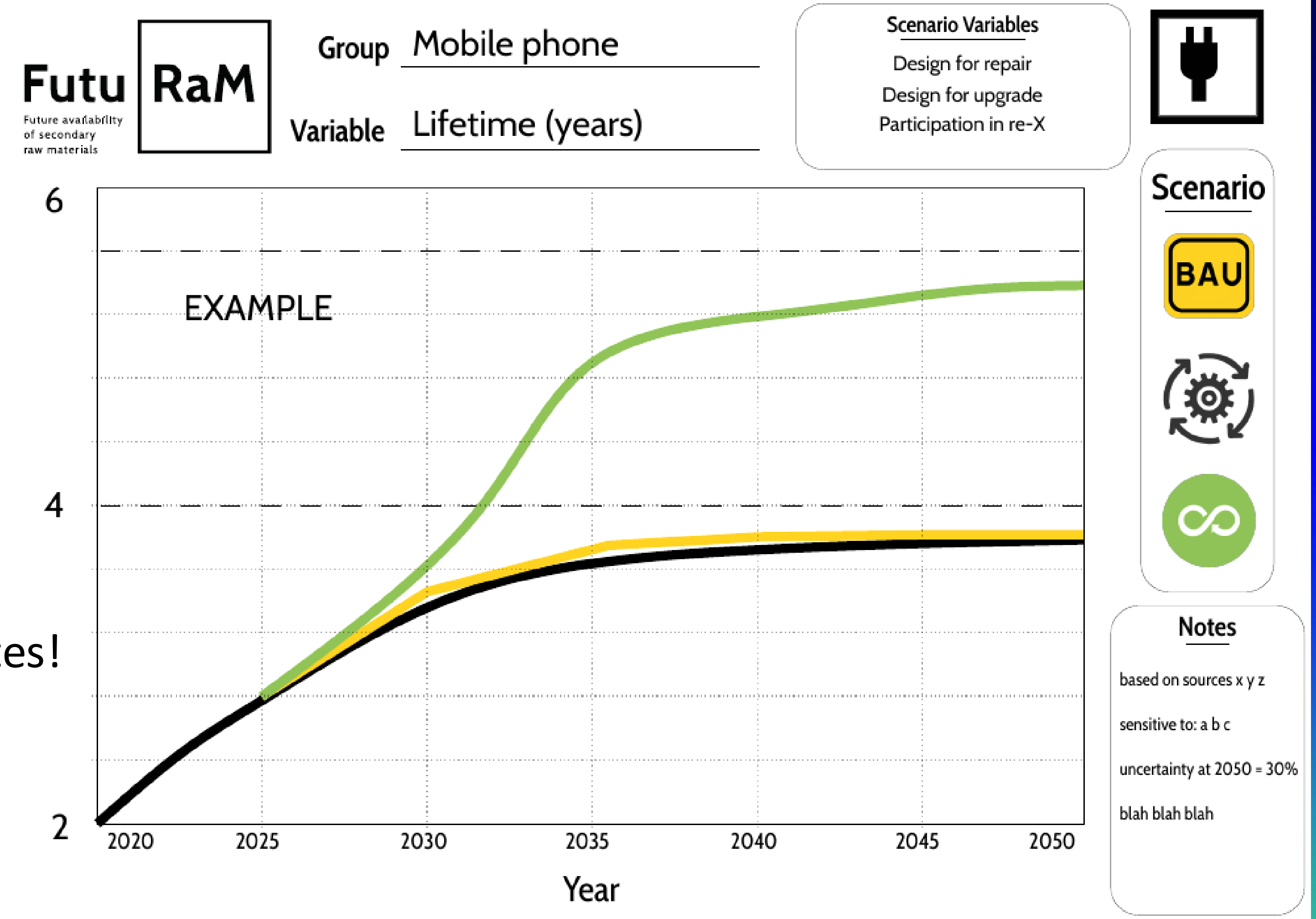
General method

BAU : forecasting based on current trends

REC/CIR: often with end points, working back

e.g: CRM act, BATT act, ELV directive

Add notes!



Important: changes in future product/waste composition **(WP task 2.2)**

Not necessarily limited to the WS model, consider also changes **recovery technology (WP task 2.3)**

Interoperability of models

Essential for

- backcasting,
- sensitivity analysis
- optimisation
- consistency

Important for

- validity
- updateability
- maintainability
- extensibility

Waste Stream Model	Scenario elements		
	x	y	z
Demand	554	0.3	234
Product Composition	34	$34 + z^{1/2}$	.....
Put-on-market	23*x	.....	.....
Lifetime	.....	.....	.....
Collection	.....	.....	.....

WASTE VOLUME AND COMPOSITION

IDEALLY THE INTERFACE IS AT THE EARLIEST STAGE POSSIBLE

WP 2 – Future Scenarios

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FutuRaM's Three Future Scenarios

Scenario I: Business-as-usual (BAU)

The BAU scenario extrapolates current trends into the future with limited change. Using forecasting techniques, it projects a potential future where there are minor advancements in resource efficiency, recovery technology, and the energy transition, but primary extraction of raw materials remains the dominant practice.

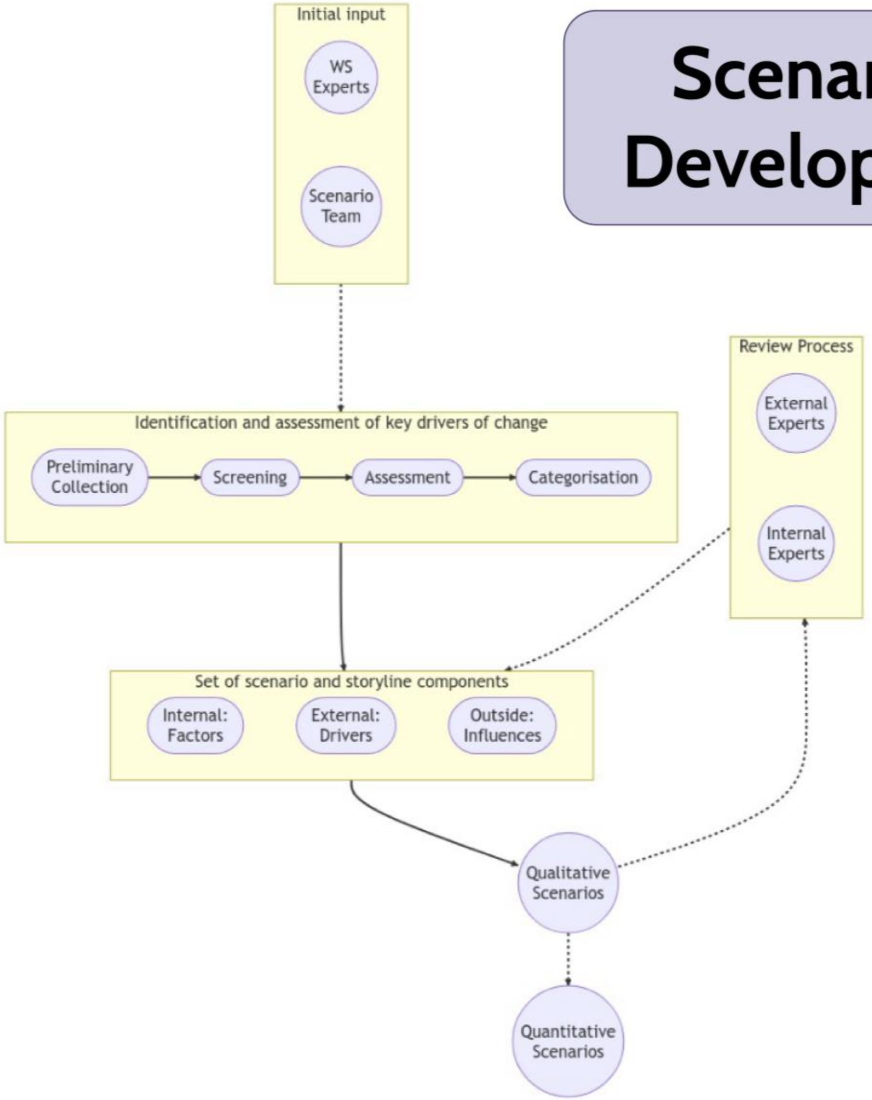
Scenario II: Recovery (REC)

The Recovery scenario imagines a future leveraging advanced technology to significantly enhance SRM recovery from waste streams. It outlines a future where the EU successfully meets its recycling and recovery targets through an effective waste management system and circular design principles [13, 14]. This scenario sees an increased recovery rate of SRMs, extensive use of digitalisation and automation in recycling processes, and new or strengthened waste regulations in line with EU targets.

Scenario III: Circularity (CIR)

The Circularity scenario captures the ideal of a fully realised circular economy, going beyond end-of-life recovery to minimise waste at every production and consumption stage. It predicts a future where the EU's targets for recycling, recovery, and circularity are met through extensive stakeholder collaboration, new business models, and increased use of renewable energy and circular economy technologies [15, 16, 17].

Scenario Storyline Development Process



Elements at each stage

28	-	preliminary
21	-	screening
17	-	FINAL LIST
11	-	internal factors
3	-	external drivers
2	-	outside factors

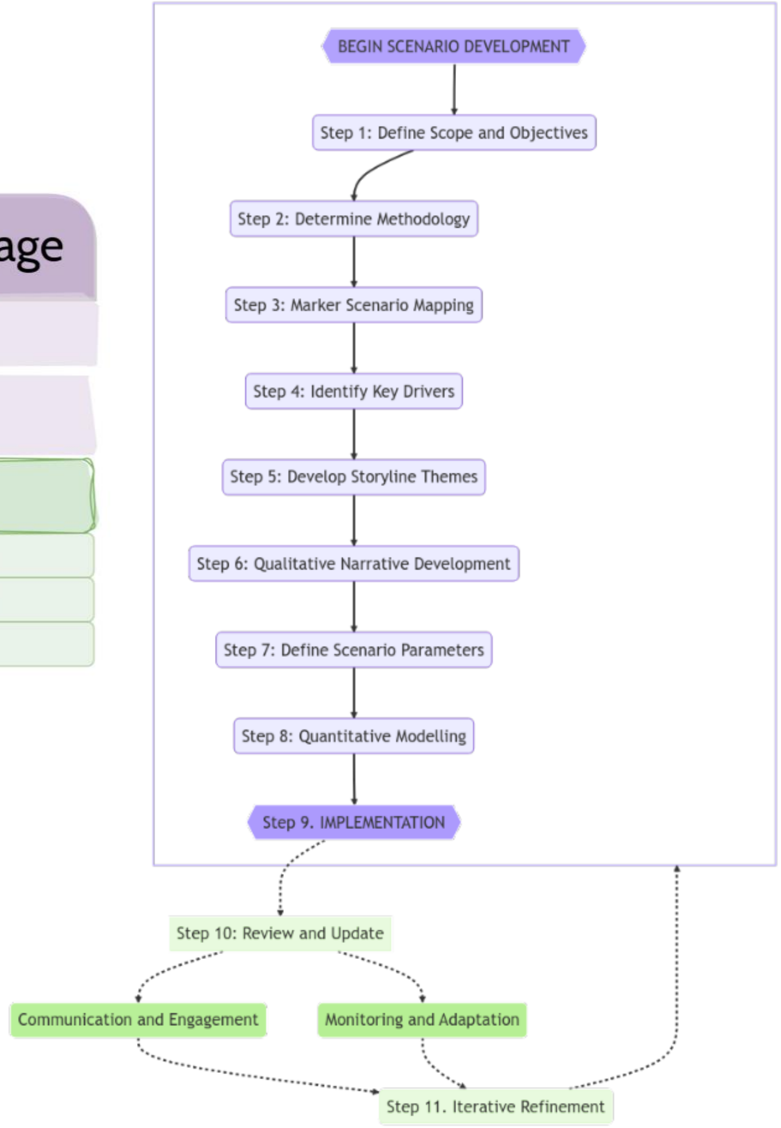


Figure 2.1: Scenario storyline development process

tech-based recovery

RECYCLE

Technological Change

Scenario elements

- **Product technology(composition)**
- **Recovery technology**
- **Recovery system development**

Waste model parameters include:

- **Lifetimes:** function of product technology
- **Composition:** function of product composition, durability, design-for-repair, etc.

Recovery model parameters include:

- **Recovery processes:** market penetration of recovery technologies
- **Transfer coefficients:** function of recovery technologies
- **Recovery system size:** BAU - set by trends in BAU, CIR & REC - defined by model outcomes within constraints

re-X strategies

REUSE

REFUSE

REPAIR

Circular Strategies

Scenario elements

- **R0-2:** Refuse, Reduce, Reuse (including 'sharing economy')
- **R3:** Repair
- **R4-5:** Refurbish and Remanufacture

Waste model parameters include:

- **Put-on-market:** function of consumer behaviour (internal)
- **Lifetimes:** function of repair rate, durability, design-for-repair
- **Waste composition:** function of product composition, durability (weight), design-for-repair, etc.
- **Collection rate:** function of consumer engagement in re-X strategies, collection infrastructure, legislation, export rate

Recovery model parameters include:

- **Transfer coefficients:** function of design-for-(re-X) strategies, recovery technology (internal)
- **Recovery system size:** function of collection rate

"Outside elements"

Not included in the scenario storylines or directly in the models. They may be considered in sensitivity analysis and optimisation but are not primary drivers in the scenario development

e.g.

- Resource supply constraints
- International trade and co-operation
- Re-industrialisation of EU
- Resistance to recovery projects ("NIMBY")

outside elements

sensitivity example two

Profitability/Feasability

EXAMPLE

Impact of Raw Material Prices and Government Subsidies on Recovery System:

Scenario:

The model tests scenarios with significant fluctuations in raw material prices. In certain scenarios, a government subsidy is introduced to set a minimum price for recycled materials, ensuring their economic viability.

Analysis:

Sensitivity analysis evaluates the effect of raw material price changes on the profitability and viability of the recovery system. It also tests the impact of government subsidies in stabilising the system against these fluctuations.

Outcome:

This analysis can reveal the dependency of recovery operations on raw material market prices and the effectiveness of government subsidies in mitigating associated risks.

outside elements

optimisation example one

Supply/demand shock

EXAMPLE

Responding to Sudden Demand Increase for a Previously Less Valuable Material (Element X):

Scenario:

The model simulates a sudden increase in demand and price for a specific material (Element X) that was previously less valuable.

Analysis:

The system's response is optimized to maximise profitability under this new market condition, involving adjustments in collection and processing priorities towards Element X.

Outcome:

The optimisation indicates the most effective strategies for reallocating resources and operations to capitalise on the increased demand for Element X, enhancing profitability.

outside elements

optimisation example two

Environmental and economic objectives

EXAMPLE

Optimizing for Environmental and Economic Goals amid Rising Carbon Emission Costs:

Scenario:

The model considers a significant increase in the cost of carbon emissions, impacting the expense of recovery operations.

Analysis:

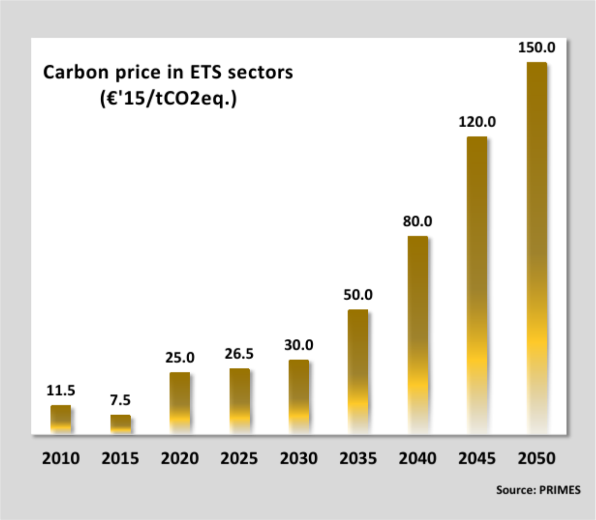
The optimisation aims to balance environmental impact (carbon footprint) with economic viability, exploring operational adjustments like adopting more carbon-efficient recovery processes or prioritising materials with higher primary carbon footprints (offsets and substitution).

Outcome:

This approach yields insights into effective strategies for maintaining profitability while minimising environmental impact, aiding the system in achieving a dual bottom line of environmental sustainability and financial health.

Carbon price in EU2020 reference scenario

Figure 8: ETS emissions and carbon prices



02.

Moving into quantification

Interpretation and quantification of scenario elements

Developing connections between the models

Interpretation

- *Waste* -

Draw connections between scenario and waste stream model elements

Waste Stream Models

Develop correlation formulae to quantify the relationships between them

Demand

Put-on-market

Composition

Lifetime

Collection

To Recovery

Demography

Economy

Product technology

Design for re+X

Participation in re-X

Future Scenarios

Interpretation

- *Recovery* -

Draw connections between scenario and waste stream model elements

Recovery Model

Develop correlation formulae to quantify the relationships between them

Process units

Transfer coefficients

Distribution coefficients

Process inputs

Process outputs

To Impact Assessment

Recovery system development

Process technology

Product technology

Design for re+X

Participation in re-X

Future Scenarios

Interoperability of models

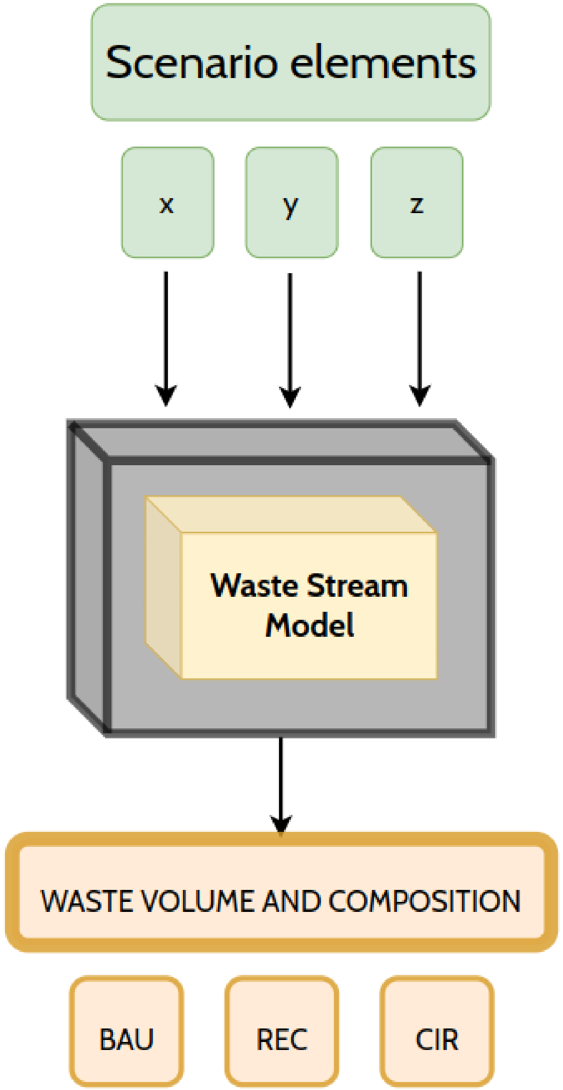
The easier way

Waste Stream model

- "black box"
- interface after collection phase

Challenging for

- validity
- updateability
- maintainability
- extensibility



Open science

"Open science" means an approach to the scientific process based on open cooperative work, tools and diffusing knowledge

(Horizon Europe Regulation and Model Grant Agreement)

FutuRaM grant agreement

1.2.5 FutuRaM's Open Science approach

Associated with document Ref. Ares(2022)3832156 - 20/05/2022

The Consortium is committed to promoting open science following UNESCO's recommendations. The research results and interpretations will be published so that they are open and transparent, respecting the confidentiality of data or findings when legitimately required. Thus, it will implement the principle as open as possible, and as closed as necessary in full accordance with the FAIR principles of open data promoted by the EU commission and across all actors and stakeholders. Concerning geospatial data, EU research organisations have a unique opportunity

The reproducibility of the project calculations and results and the facilitation of past end of project data update will be the objective of a task about protocols (cf. Section 1.2.1.6). This concerns the algorithms, workflows, models, software and data in open accessible repositories.

Interoperability: Variables and value names will be constructed and provided following general data processing conventions common to the research subject. Examples of vocabulary information to be managed within the project will be e.g., units of observation, list of variables with the name and label to each variable. After project closure, metadata of opened datasets will be made available via FAIR compliant repository for research and re-use as described above. Formats used for the datasets are anticipated to be e.g. csv, txt.

Reusability: Potential re-utilisation will be enabled and the quality of the data ensured by careful documentation of data collection methods as well as the contents of the datasets. After the project completion, the final datasets are open accessible in the public repositories SRM-KB.

03.

Task 2.2 and 2.3

Assessment of:

- future product composition
- future recovery technology

Integration of this into the models

Tasks 2.2.1 and 2.2.2

- Survey of future product composition and recovery technology
- Partners to add items to the spread sheet

XII.4. Consortium partner contributions to WP2

Table 1.6 lists the consortium partner contributions to WP2, in terms of person months for each sub-task. The table is based on the FutuRaM grant agreement [21].

WP #	WP Name	Total PMs	Task No.	Start	End		WEEE Forum	UNITAR	BRGM	Chalmers	GTK	LMU	RECHARGE	SGU	TUB	Leiden Uni	VITO	Empa	UCL	Total
						ALL TASKS	3	19	8	10	2	12	1	1	21	28	4	8	7	124
2	Foresight on Secondary Raw Materials	151.0	2.1	2022-06-01	2023-11-30	Develop scenario storyline	1	5	1	2				.5	2	1		1		13.5
			2.2	2022-08-01	2024-01-30	Integrate future technologies into the scenarios	1	4	2	6	1	1	.5	.5	6	1	2	1	3	29
			2.3	2022-12-01	2024-01-30	Forecast material composition and products for each scenario	1	4	2	2	1		.5		8	4	2	2		26.5
			2.4	2023-11-01	2025-05-31	Quantify environmental and socioeconomic impacts of SRM recovery under each scenario		2	2			11			2	11		3	4	35
			2.5	2025-06-01	2026-04-30	Assess the environmental and socioeconomic impacts and bottlenecks of future SRM recovery		4	1						3	11		1		20

DISCUSSION TOPICS

- **External elements**
  - **Demographic** (add age, gender, cultural background?)
  - **Economic** (is GDP enough?)
  - **Energy Transition** (which scenario to use?)
- **e-Mobility transition** (keep equal across scenarios?)
- **Connection of UNFC to the scenarios** (???)
- **Something else?**

04.

Discussion

Choose your own adventure...

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External elements: Demographics

*"Within the FutuRaM, project no specific population group will be targeted. In contrast, the consortium is aware that **research often has a diversity problem** since many groups are underrepresented, e.g. women, ethnic minorities, people with disabilities and socially disadvantaged populations and **we will consider specific measures** that will help to address specifically these groups."*

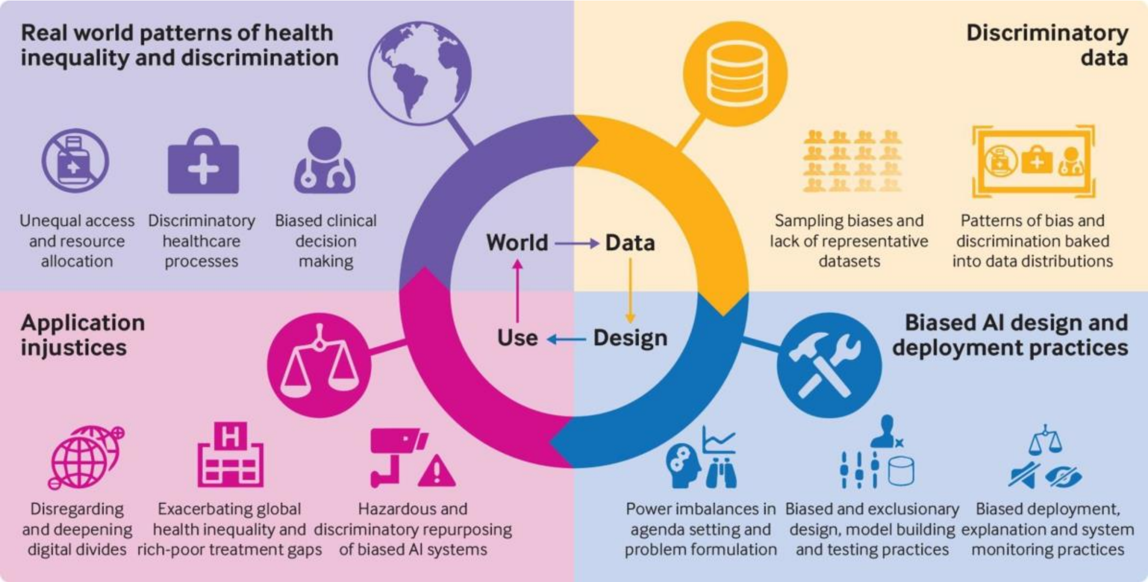
In the modelling of WP2 and 4 (foresight and stock and flow models), consumption of household electronics may increase with increasing gender equality, and behavioural aspects of waste separation which could be an aspect of foresight of stock and flows.

— **FutuRaM Consortium Agreement**

Are we missing something?

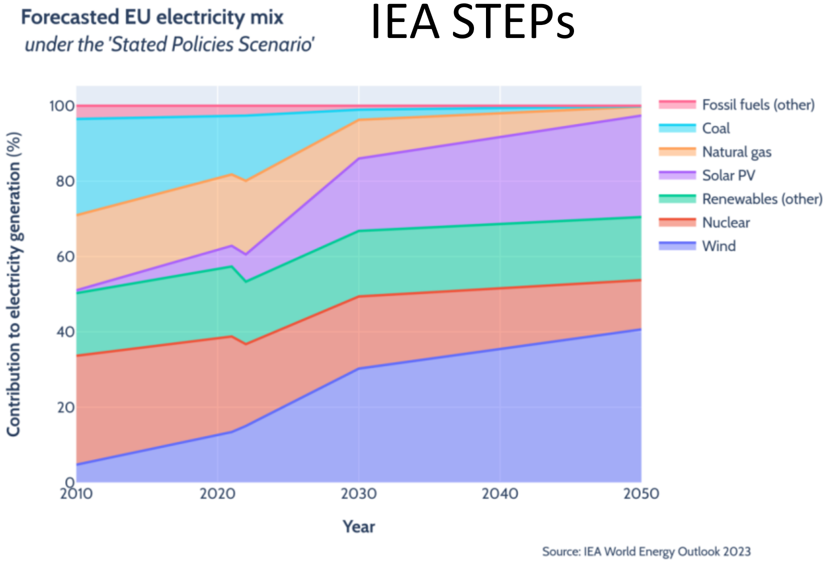
- Aging ↑
- Migration ↑
- Urbanisation ↑
- Gender equality ↑ (?)
- Number of people per household ↓

Add data from census/household surveys?
Bias can lead to incorrect modelling results.

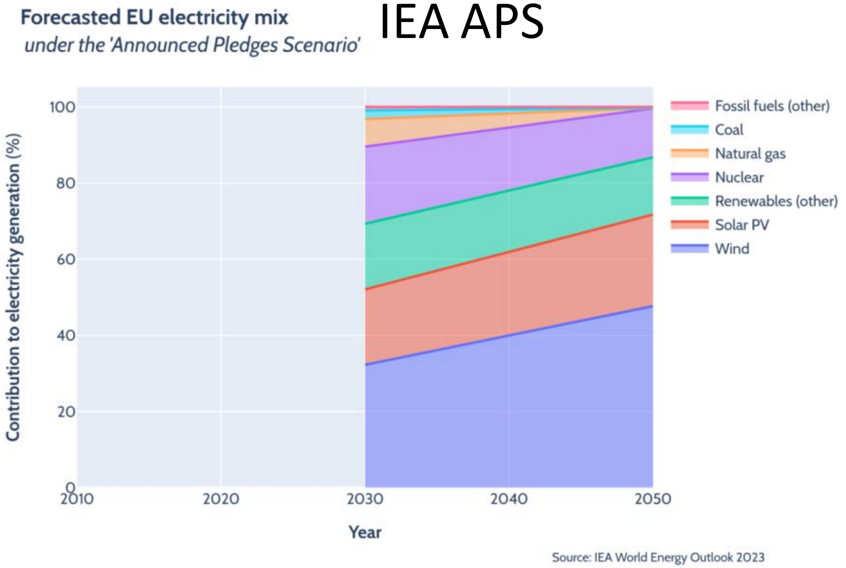


External elements: Energy Transition

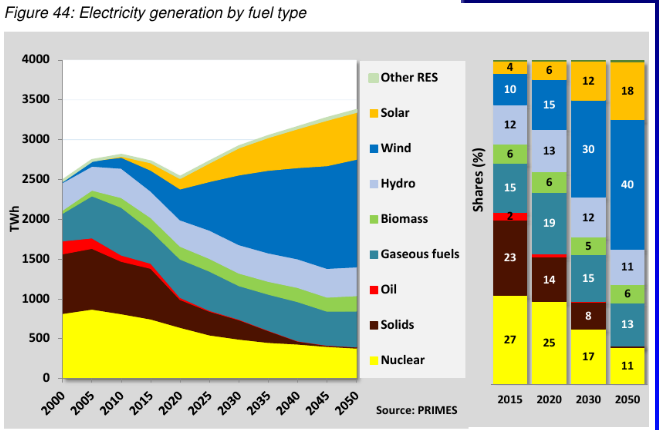
IEA STEPs



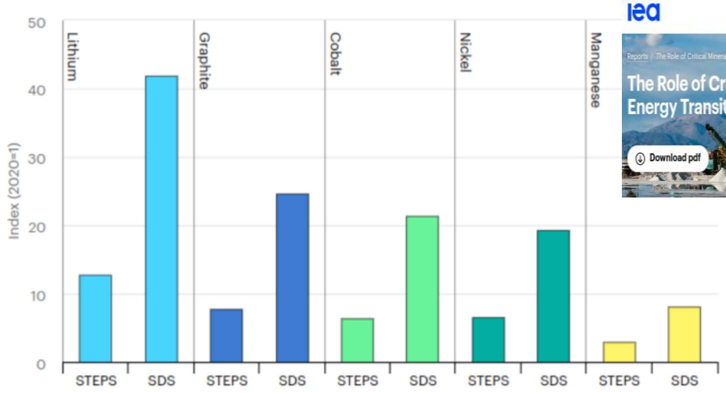
IEA APS

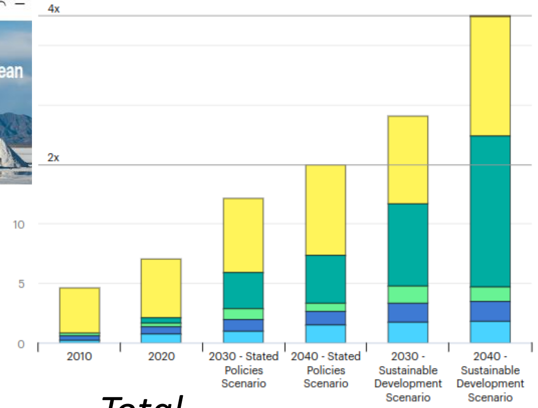


EU2020 reference



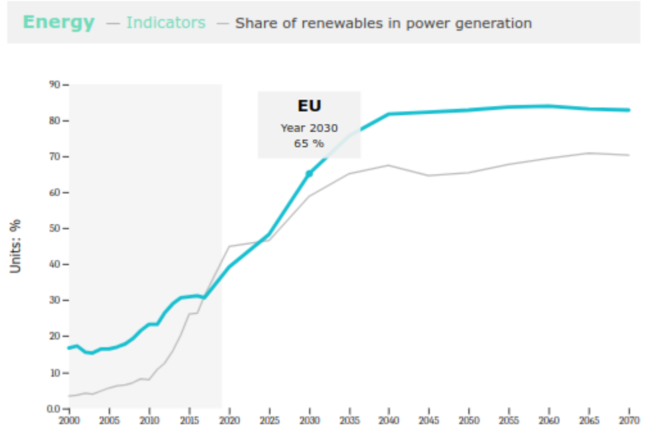
Choice of scenario makes a big difference



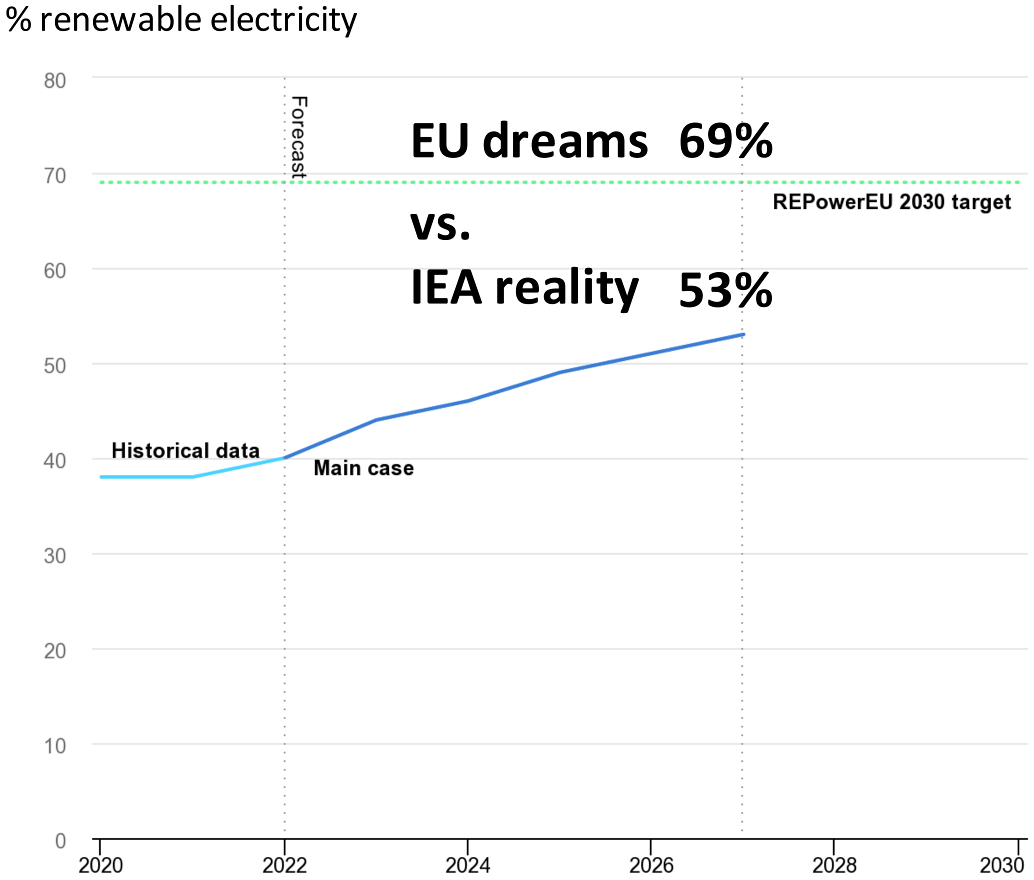


Change in demand *Total*

JRC GECO 2022 reference



The case for pessimism



IEA and EU analysis

In addition to the internal conflict among member states [81], a recent IEA analysis concluded that EU's renewable energy expansion is constrained by inadequate policy support, complex permitting, and grid upgrades' pace. [79]

Current forecasts indicate that the solar PV and wind capacity expansions fall short of the REPowerEU plan's renewable electricity targets for 2030. The European Commission Staff Working Document states that achieving a 69% share of renewable electricity requires 592 GW of solar PV and 510 GW of wind by 2030, translating to annual additions of 48 GW for solar PV and 36 GW for wind [82]. These figures significantly exceed the IEA's

Official dissent to EU targets

Belgium

Belgium supports the directive while voicing *"serious concerns"* over the feasibility of increased renewable energy targets, citing *"demographical and geographical limitations"* and the presence of energy-intensive industries. The national contributions and sectoral sub-targets are deemed *"extremely difficult to achieve"* and potentially *"unachievable"* within the proposed timeline.

Poland

Poland boasts a rapidly growing renewable sector but cannot support the proposed directive, stating it is unrealistic and could destabilize the energy grid and security. They assert that the targets lack realism and flexibility, and stress that the energy transition should be *"accessible to society"* and in favor of European industry.

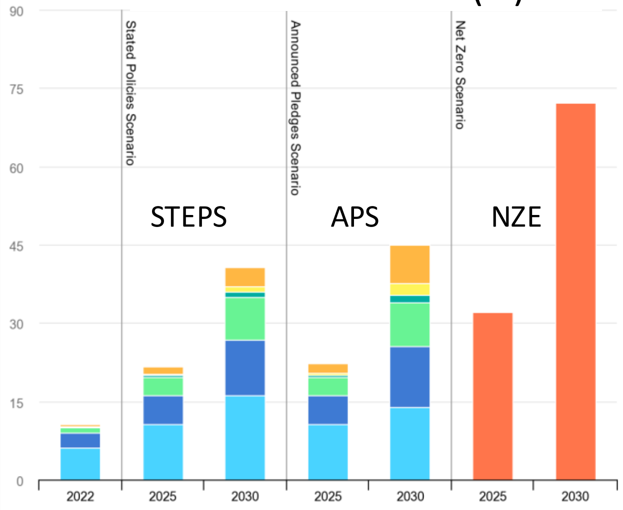
+ several more

External elements: e-Mobility transition

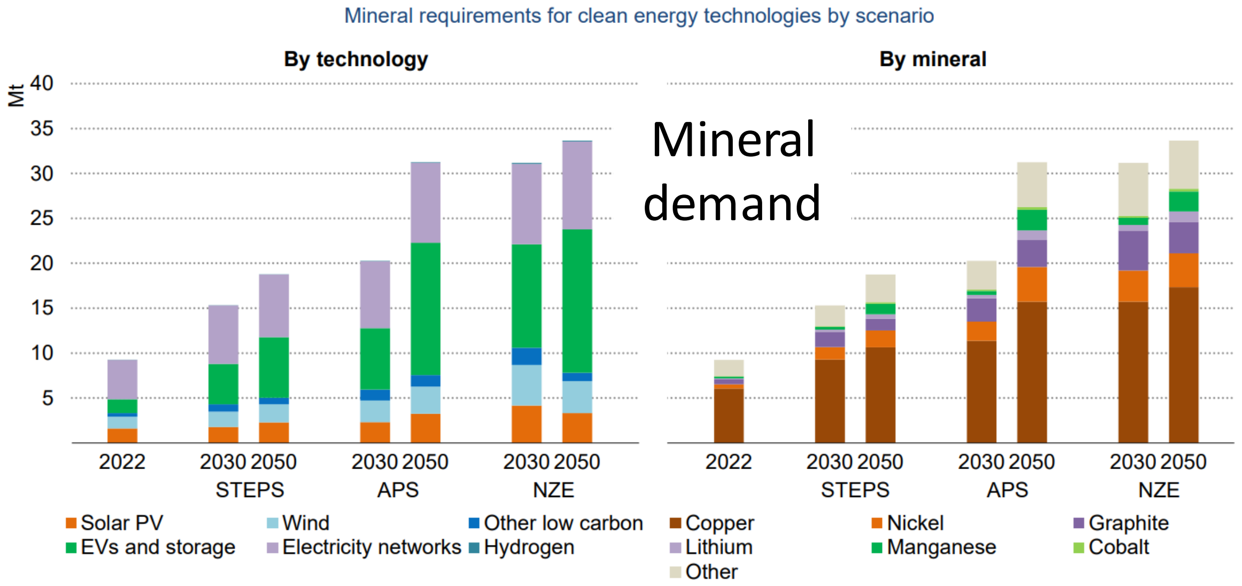
IEA scenarios

Colors = region

E-vehicle Sales (%)



Mineral demand



EU2020 reference scenario

Figure 40: Total energy consumption in transport by fuel

Energy mix

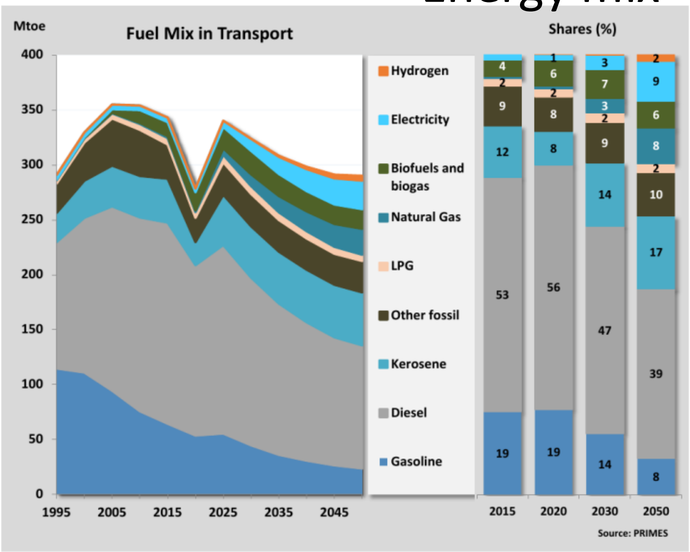
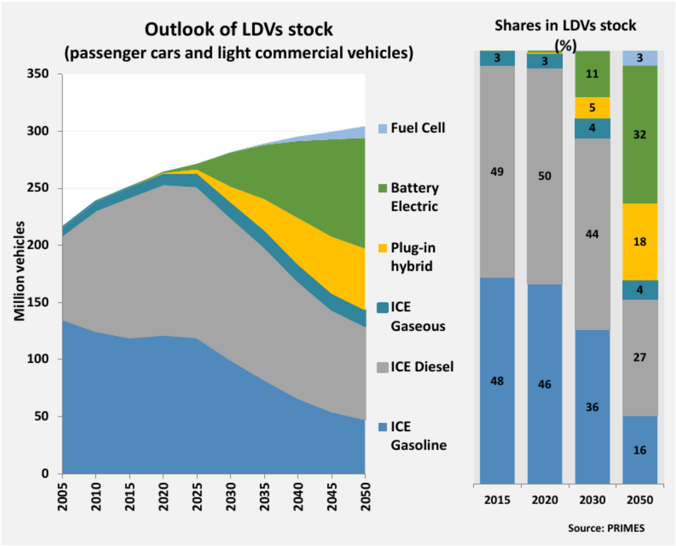


Figure 42: Outlook of LDVs stock by type and fuel

Stock



UNFC and future scenarios

?

I assume that they will need to align their assessments to the scenarios and provide their classifications as a matching set...

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