CLIMATE NEUTRAL BY 2035

TAL TECH

How to find appropriate balance between applied and fundamental research

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8.11.2023

TALLINN UNIVERSITY OF TECHNOLOGY

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"In my view, basic science is the best thing that mankind pursues—not so much because it leads to new applications but because it leads to new understanding. For me, there's no greater pleasure than the joy of discovery. With basic research, you don't begin to recognize the applications until the discoveries are in hand."

Prof. Dan Kleppner, MIT

co-inventor of the hydrogen maser

"I wasn't dreaming of developing the GPS"

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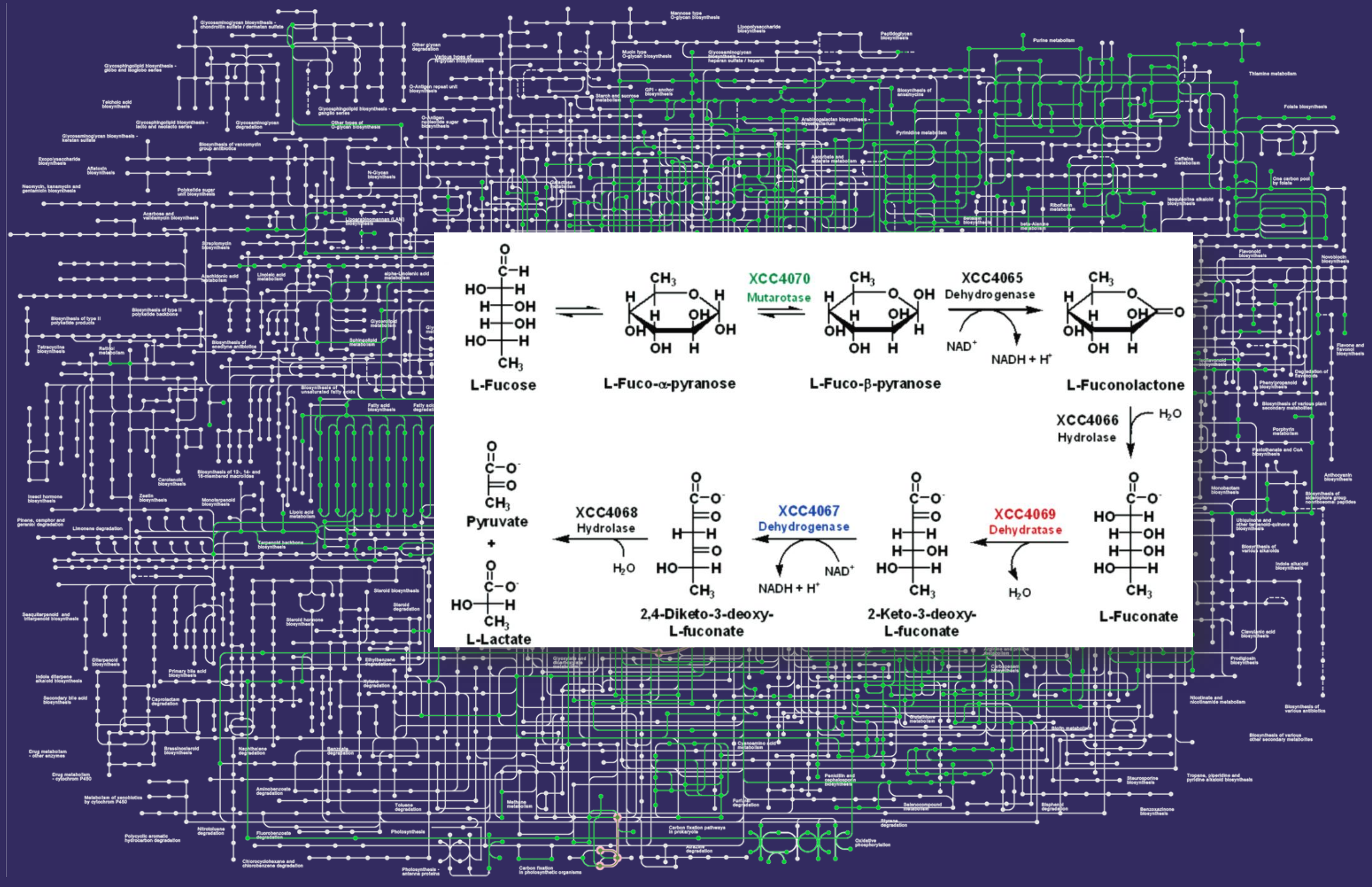
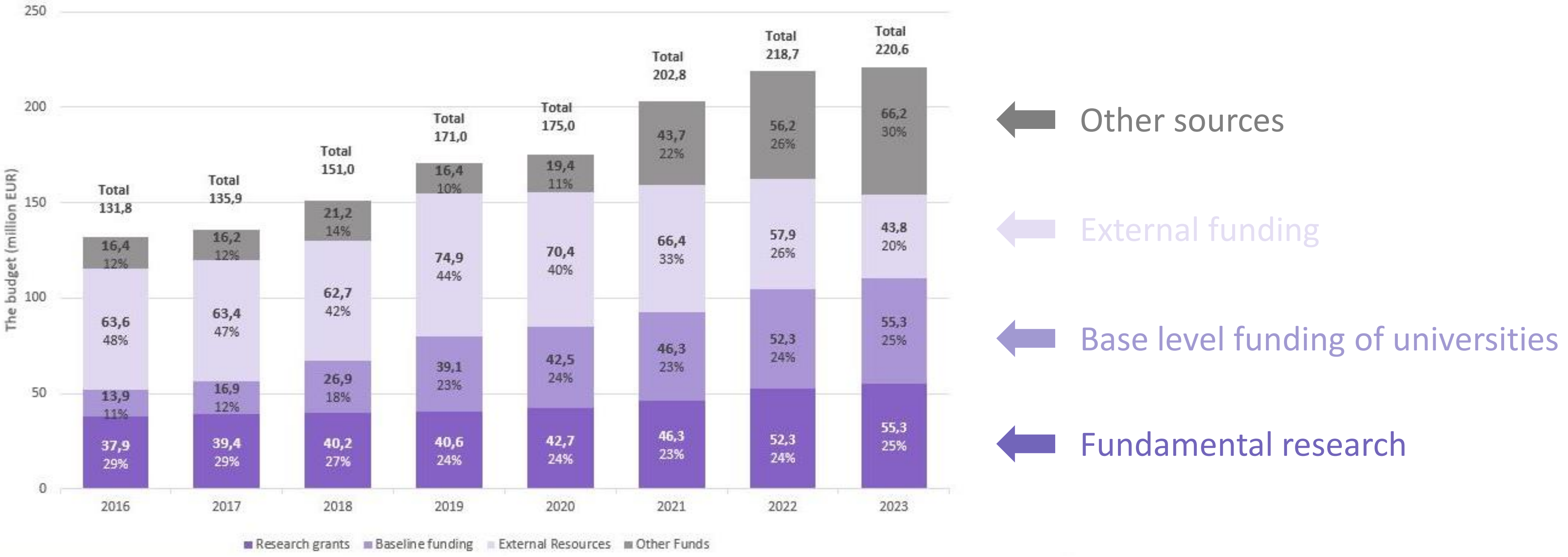

L-Fucose
L-Fuco-α-pyranose
XCC4070
Mutarotase
L-Fuco-β-pyranose
XCC4065
Dehydrogenase
NAD+
NADH + H+
L-Fuconolactone
XCC4066
Hydrolase
H2O
L-Fuconate
XCC4069
Dehydratase
H2O
2-Keto-3-deoxy-
L-fuconate
XCC4067
Dehydrogenase
NAD+
NADH + H+
2,4-Diketo-3-deoxy-
L-fuconate
XCC4068
Hydrolase
H2O
Pyruvate
+
L-Lactate

CHALLENGES FOR A SMALL COUNTRY/ECONOMY

- The level of basic research funding is dictated by government budget, recent increases in budget march in lockstep with inflation



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FINDING THE BALANCE

- Countries with large economies have the capacity to fund fundamental research from their state budget or country-wide measures
- Small economies with limited budgets are more dependent on ”targeted research” (due to bigger external funding) where researchers have less freedom to study and excel in areas that have not yet been recognized as having real-life applications

- A quote from a recent ScienceBusiness article* on the topic of FP10 reads like this:

"*One key question will be how much of the programme should cover targeted research that helps the EU achieve its political priorities.*

It's a two-fold problem. One is how strictly priorities should be defined for the seven-year programme and how much room should be left for emerging priorities – the rise of AI or EU enlargement, for example. The ***other one is how to balance targeted research for addressing specific challenges and allowing scientists free rein, which in the long run tends to produce knowledge that could address crises politicians could not have anticipated*** *– just think of the fundamental research that enabled the rapid development of COVID-19 vaccines.*

The latter is one of the key complaints about the current Horizon Europe research programme*. For universities, it's too focused on closer-to-market research, and they're* ***struggling to find space for their activities in Pillar 2****, the part of the programme that funds big collaborative projects.*"

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*https://sciencebusiness.net/news/fp10/exclusive-heres-what-member-states-have-mind-fp10

PILLAR I – AN EXCELLENT SOURCE FOR BASIC RESEARCH FUNDING… FOR SOME

- The researchers from the Baltic states apply for ERC funding like any other – yet are not successful - and it is not because of lack of trying or the lack of excellence… is there bias, or is it just paranoia?
- Latvia and Lithuania (26 evaluated CoG applications for LIT) have thus far had 0 ERC grant holders

- Statistics on CoG applications success rates across LS/PE/SH

  Data 2013-2021

- Overall success 12,8%

Country	Awarded	Evaluated	Success rate
Iceland	4	17	23,5%
Israel	146	675	21,6%
Luxembourg	7	33	21,2%
Switzerland	166	814	20,4%
Germany	489	2784	17,6%
Netherlands	246	1470	16,7%
Austria	82	520	15,8%
Belgium	104	705	14,8%
France	341	2402	14,2%
United kingdom	475	3736	12,7%
Denmark	74	594	12,5%
Norway	53	448	11,8%
Sweden	102	881	11,6%
Ukraine	1	9	11,1%
Ireland	43	393	10,9%

Country	Awarded	Evaluated	Success rate
Portugal	47	452	10,4%
Czech republic	20	206	9,7%
Hungary	16	188	8,5%
Spain	178	2134	8,3%
Italy	160	2067	7,7%
Finland	56	766	7,3%
Cyprus	4	60	6,7%
Greece	16	284	5,6%
Poland	12	276	4,3%
Türkiye	8	191	4,2%
Estonia	3	72	4,2%
Croatia	2	49	4,1%
Serbia	1	26	3,8%
Romania	4	105	3,8%
Slovenia	1	76	1,3%

KEY TAKEAWAYS - IMPORTANCE OF FUNDING BASIC RESEARCH

- Everyone understands that breakthrough discoveries and success stories are still based on information obtained from basic sciences and basic research.
- Today's new technologies and economic models are possible because the necessary breakthroughs were made in the relevant basic research decades ago, and our success is based on those basic research from decades ago.
- If we no longer fund basic research today, in twenty years there will no longer be a foundation on which to build new success stories. The **question is now finding a balance.**

- The example of Iocsagen – for decades studied human and bovine papilloma virus – perfected technologies related to protein (antibodies) production
- Innovator of the year award 2023 – over 100 clients, 500 projects, produced more than 3000 molecules

(20 mEUR turnover, 6 mEUR profit).

Prof. Mart Ustav
virologist

ICOSAGEN CELL FACTORY

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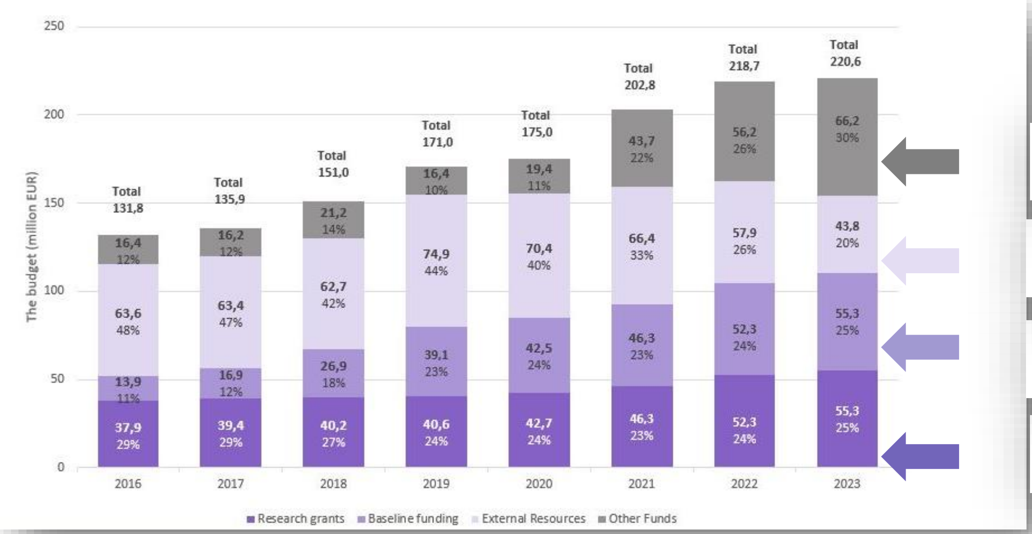
FP9 – MORE APPLIED SCIENCES AND POLICY DRIVEN RESEARCH

- There seems to be consensus that FP9 is a bit out of balance as there are far too many calls with very specific research (or even industry-related) problems needing to be solved
  - Collaboration with industry
  - Pre-set values for TRL
- What are the potential reasons behind this kind of tactic?
  - EU has set itself ambitious goals in areas of both green and digital transition
  - The hope and wish is that research will drive the innovation to provide solutions
  - EU is a kind of a customer that directs research towards applicability and commercialization
  - The bigger competitors of EU (USA and China) have vast industries that do research and make money along the way. Since EU does not have that many research intensive industries, calls for targeted research with university participation could be a way to remediate the current situation. The fear is that if researchers are let loose to what they wish, the innovation gap between EU and major competitors will worsen still.
- What are potential drawbacks of such tactic?
  - By funnelling money into pre-set topics that focus only on application, scale-up and commercialization of mature technologies, and not so much on fundamental research, there is the threat of suffocating the ability to discover new science that leads to new tech

"With basic research, you don't begin to recognize the applications until the discoveries are in hand"
Dan Kleppner

HOW HAS POLICY DRIVEN FUNDING CHANGED RESEARCH LANDSCAPE IN ESTONIA

- Since 2016, the program financing sectoral R&D (funded by EU) has supported scientific advisor positions at the Ministries and Governement Office, this has been a game changer!
- The scientific advisors that work hand-in-hand with politicians and policy makers provide support in designing measures to fund research in fields that are divided between the 14 different ministries of Estonia (eg. Ministry of Social Affairs, Ministry of Education and Research, Ministry of he Enivronment etc.)
- While the Estonian Research Council provides approximately 60 mEUR of research funding (program grants) then the different Ministries hold a portfolio of also about 60 mEUR to provide research funding through different thematic R&D programs



Other sources

External funding

Base level funding of universities

Fundamental research

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HOW HAS POLICY DRIVEN FUNDING CHANGED RESEARCH LANDSCAPE IN ESTONIA

- The introduction of thematic research development programme – with focus on valorization of different varieties of resources. Piloted in 2020, the ResTA programme brought together universities and industry.
- ResTA – support for research and development in the field of resource valorisation focused on three areas:
  - Research related to Estonian mineral resources
  - Research on decomposition and chemical valorisation of wood
  - Research on valorisation of food raw materials and the separation of food components
- The program sparked new interest by various industries to collaborate more with universities and to find smart solutions to make their processes more effective – as a bonus the projects provided trained human capital to tender the needs of the industrial job market

- Good things happen from collaboration – transition to renewable raw materials – resuscitation of wood chemistry!

HOW POLICY IS DRIVING CHANGES IN INDUSTRY

- One of the largest industries in Estonia has to do with oil shale (energy, chemical, mining)
- Due to carbon taxation and very soon the ban on any burning of fossil fuels, three major Estonian oil shale centered companies are changing their direction and are looking to universities to innovate new technologies

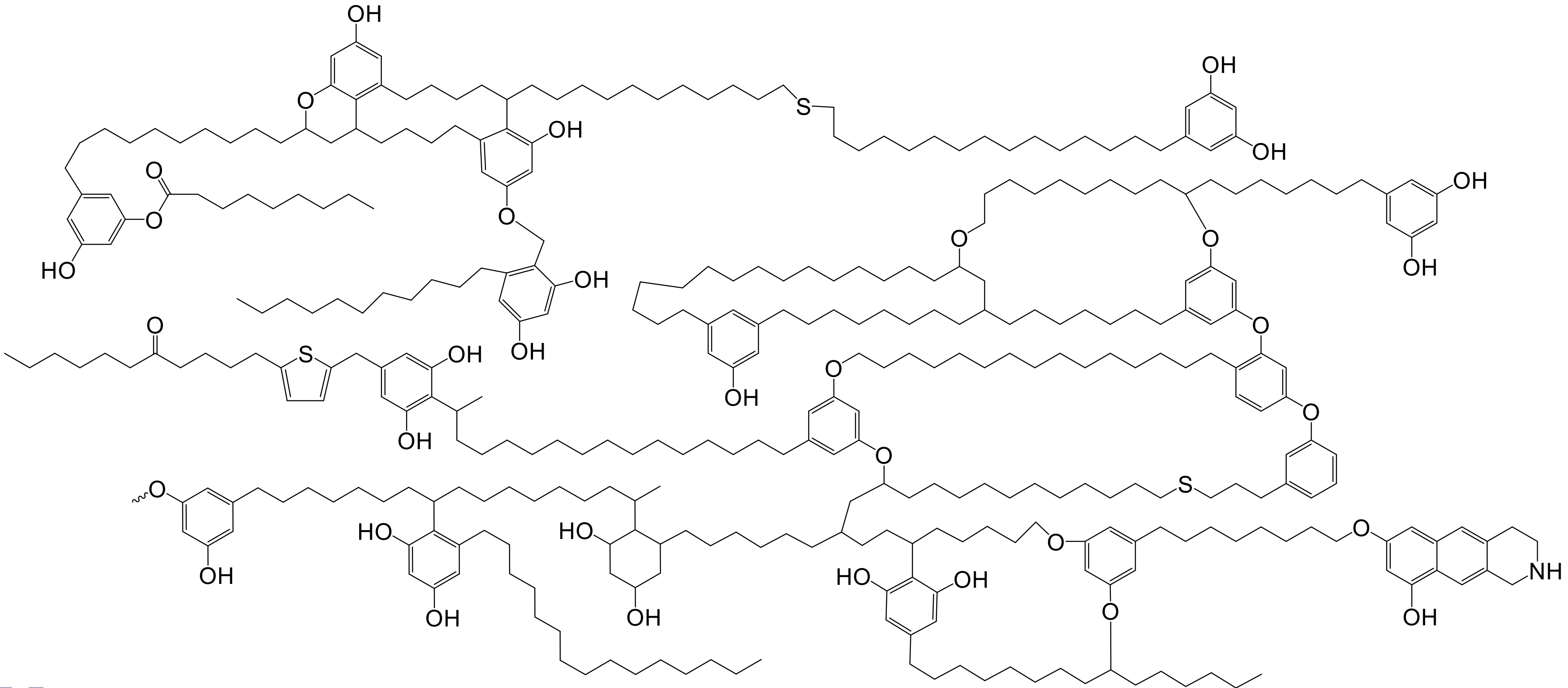
Eesti Energia	VKG Viru Keemia Grupp	Alexela
Provides 50% of Estonias electrical energy needs	**Largest chemical industry in Estonia**	**Largest exporter of shale oil products from Estonia**
Phasing out oil shale based energy production; focuses on solar and wind;	Largest shale oil-derived fine chemical producer in Estonia; phasing out oil shale;	Is looking to shut down traditional GHG intensive shale oil extraction;
Investigates oil shale ash derived energy storage solutions and circular economy inspired co-pyrolysis technologies to produce fine chemicals from old tires and plastics; two industrial doctoral positions with TalTech;	Is in final stages of planning to build a wooden bioproducts mill (dissolving pulp and green energy); will invest in opening up a wood chemistry masters curriculum at TalTech;	Environmentally friendly chemical transformation of shale-oil kerogen into fine-chemicals; co-funding an industrial chemistry lab at TalTech;

ALTERNATIVE TRANSFORMATION OF ESTONIAN OIL SHALE

- Oil shale is one of the abundant mineral resources in the world. In Estonia it is the richness and torture for the country:
  - it is good for the cheap energy production and for energetical independence of the country
  - at the same time its mining and use causes severe environmental problems;
- In 2022 over 10 billion tons was mined of which:
  - Electricity 4,341,000 MWh (Eesti Energia)
  - Chemicals – ca 3 000 T (VKG)
  - Oil production 1 100 000 T (VKG, EE + Alexela)
- The question asked by Alexela was if the energy-intensive pyrrolysis step could be skipped to convert oil shale organic matter directly into more valuable chemicals (platform chemicals for chemical Industry)
  - To create any direct conversion method for a substance, an organic chemist must know the chemical structure of the object.

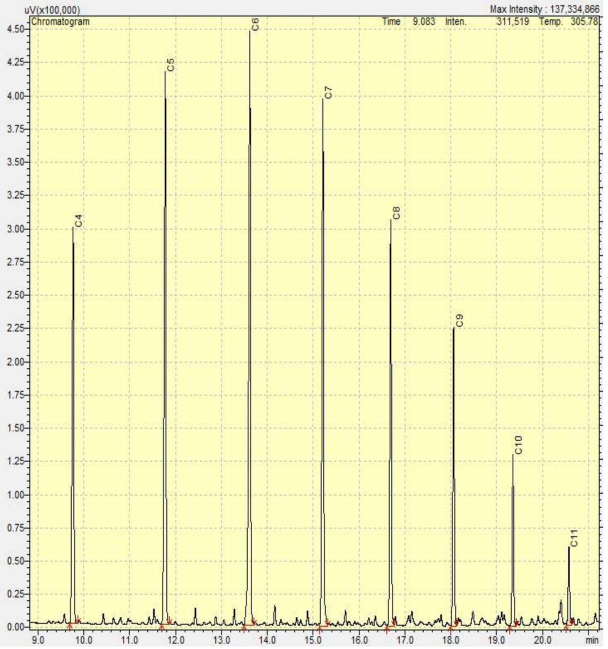
COMPLEX STRUCTURE OF KUKERSITE IS RICH IN CHEMISTRY

- Estonian chemist Lille proposed in 1999 that the main structural elements of the native oil shale are the derivatives of 1,3-benzenetriols (resorcinols) connected with each other by aliphatic carbon chains



ESTONIAN KUKERSITE IS A SUPERIOR RAW MATERIAL

- The total organic content (TOC) is above that of oil shales found in USA or the Middle East and can be readily converted into dicarboxylic acids
- Oil shale organic matter can be converted into dicarboxylic acids in a 95% efficiency utilizing wet air oxidation (WAO)
- Alternatively, nitric acid oxidation is an option with yields close to 40%
- Dicarboxylic acids are precursor molecules to polymers such as nylon but are also one chemical conversion away from being an invaluable source to **military and defense industry** as plasticizers for explosives (as dicarboxylic acid esters.. that’s the cheapest part).
- The team led by **prof. Margus Lopp** has taken oil shale valorization to a new level thanks to the policy to go carbon neutral



Oil shale	TOC,%	Conversion,%	Yield[a] of DCA, %
Kukersite	35.1	95	10.8
Green River (USA)	13.0	93	4.8
Jordan	12.7	82	2.8

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FINDING SOLUTIONS TO CRITICAL WAR-TIME AND POST-WAR PROBLEMS

- Only ten years ago, Egypt was considered to be the most mined part of the world (affecting 25,000 km^2 of land)*
  - Egypt (23 million, mostly in border regions); Angola (9-15 million); Iran (16 million); Afghanistan (about 10 million); Iraq (10 million); China (10 million); Cambodia (up to 10 million); Mozambique (about 2 million); Bosnia (2-3 million); Croatia (2 million); Somalia (up to 2 million in the North); Eritrea (1 million); and Sudan (1 million). Egypt, Angola, and Iran account for more than 85 per cent of the total number of mine-related casualties in the world each year.
- Today, the situation has changed, vastly:
  - An estimated 200 000 km^2 of land in Ukraine is mined.
  - 10 to 737 years to demine with current technologies.
  - The cost of demining Ukraine is estimated to 50 billion EUR.
- >1 billion USD had been spent on humanitarian demining R&D by the year 2000.
  - Marginal advances in existing technologies do not offer a scalable solution.
  - Actual need for massive humanitarian demining has never been closer to Europe and it has never been as massive as now.
  - Expectation for fast-track solutions.
- Ukrainian minefields have already and will even more reduce the global food supply, driving up food prices and increasing poverty.

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*https://landminefree.org/facts-about-landmines/

SOLUTION: COLLECTIVE RESEARCH, DEVELOPMENT AND INNOVATION INITIATIVE FOR NOVEL HUMANITARIAN DEMINING TECHNOLOGIES DEVELOPMENT

- Developing novel robotics and AI systems
- Novel sensing modalities, sensing methods and sensors for detecting explosives (visual, chemical, magnetic, etc.)
- Novel unmanned devices (autonomous robots, drones etc) development for detection and clearance with efficiency orders of magnitudes higher than current technologies and which do not recure putting personnel at risk in the field
- Cost-effective and rapid manufacturing of demining technologies scalable to permit demining at reasonable cost at scales
- Novel logistic, maintenance and transportation procedures to deliver and maintain clearance operations in highly uncertain and dangerous environments
- Data management and data sharing methods for collecting knowledge of mines and demining operations
- Algorithms for detection and classification of explosives in natural environments
- Citizen science methods and platforms for identifying and reporting explosives
- Capability development and deterrence (market facing activities focused on demining of Ukraine).

THANK YOU!

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