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NOVel cheap and Abundant Materials for catalytic biomass conversion

Towards Next Generation Catalysts replacing Critical Metals

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Building Scientific Alliances between Japan and EU

Prof. Emiel Hensen,
Technische Universiteit Eindhoven

CRM InnoNet 3rd Workshop
Bruxelles, February 10th 2015

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Project background

EU NMP call FP7-NMP-2013-EU-Japan - coordinated call with the JSTA

Development of new materials for the substitution of critical metals

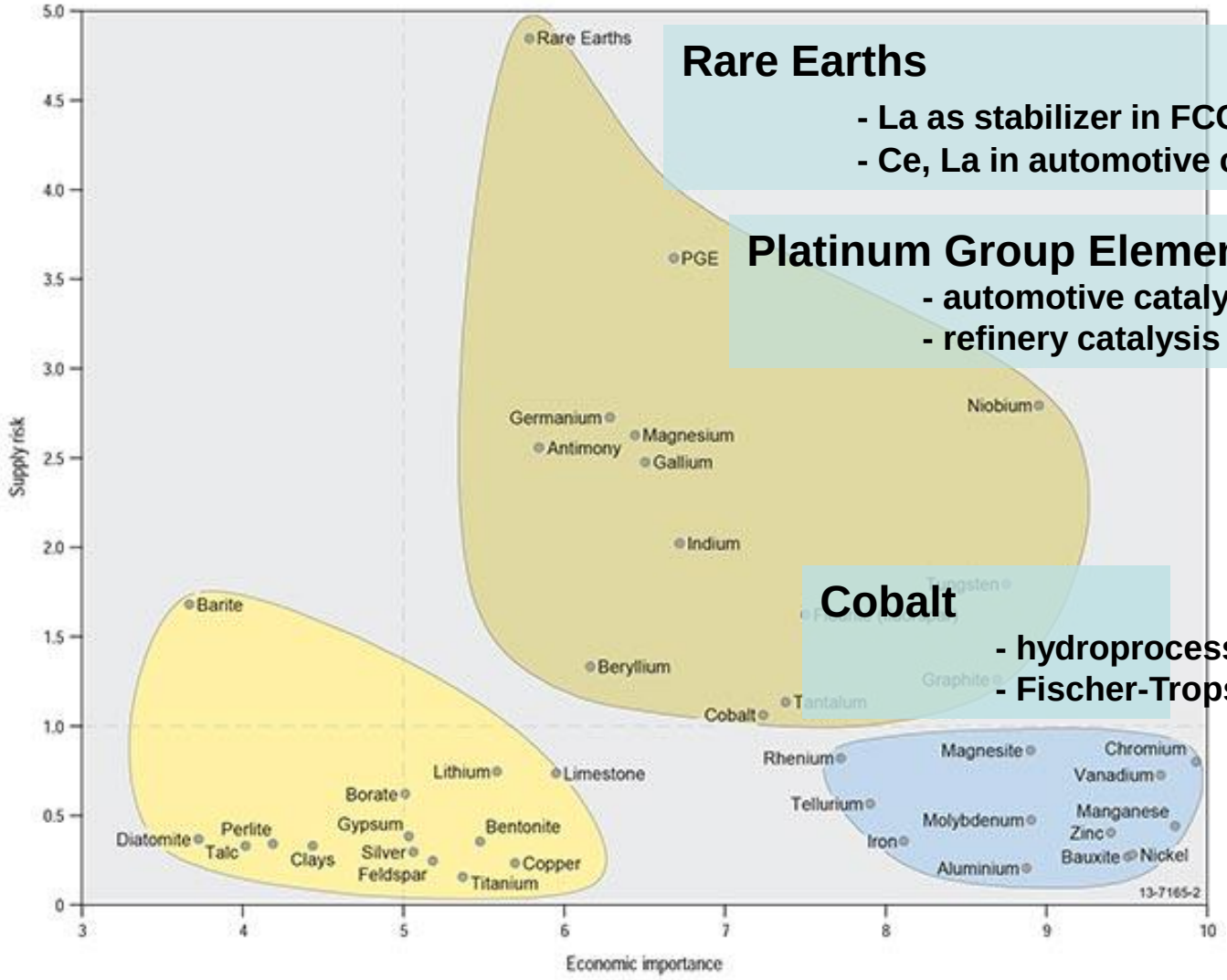
- Concern about critical raw materials use
- Ad-Hoc Working Group: *14 criticals metals* whose supply causes concern

- Risk to security of supply: platinum group metals (PGM) / rare earth (RE) metals
- Catalysts used in production all chemicals/fuels in our modern society
- Catalysts: one of six major uses of critical metals
- Catalyst industry: 13 billion USD → turnover 1800 billion USD chemicals industry

- Decrease dependence on critical metals in catalysts

- In consultation with industry
  - Focus on novel catalyst technology replacing/avoiding PGM and RE
  - Use extensive 'design' knowledge to develop next generation of catalysts
  - Apply novel catalysts to renewable feedstocks
  - Significant opportunities to make step changes in innovation and societal impact

Critical Raw Materials EU



Rare Earths

- La as stabilizer in FCC catalysts
- Ce, La in automotive catalysts

Platinum Group Elements

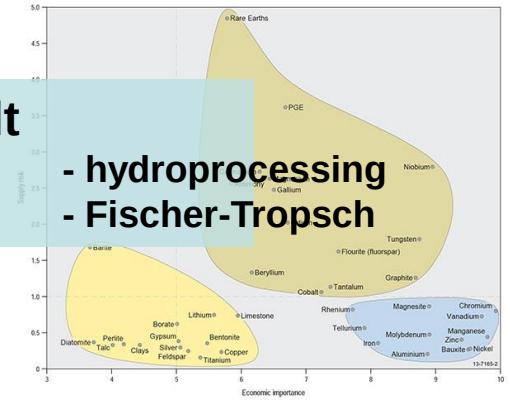
- automotive catalysis
- refinery catalysis

Cobalt

- hydroprocessing
- Fischer-Tropsch

European Commission Enterprise and Industry, 2010

Critical Raw Materials issue



- Cobalt critical raw material
- Cobalt considered conflict mineral
  - 50% supplied by Democratic Replubic Congo
  - 50% world reserved by DRC

- High economic importance in hydroprocessing catalysts (Shell, Albemarle, Topsoe)

Review

Economic and technical impacts of replacing Co and Ni promotion in hydrotreating catalysts

Applied Catalysis A: General 458 (2013) 169– 182

S. Eijsbouts[a,*], G.H. Anderson[b], J.A. Bergwerff[a], S. Jacobi[c]

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[b] *Albemarle Corporation, 2625 Bay Area Blvd., Suite 250, Houston, TX 77058, USA*
[c] *Albemarle Corporation, Parc Scientifique Einstein, Rue du Bosquet 9, 1348 Louvain-La-Neuve, Belgium*

- Alternatives: toxicity, critical (PGE), expensive

- Most promising: 50% decrease in space velocity, infeasible in every refinery
- Increased fuel cost, lower margins, lower competitiveness of European refineries

- Focus on New Chemical Processes/Future Feedstock than Conventional Processes

Overarching Objective

"to construct an innovative science base of novel catalytic technologies to enable the conversion of lignocellulosic biomass to useful and valuable organic chemicals, polymers, transportation and heating fuels"

"eliminate the use of critical raw materials for these processes"

"develop and demonstrate new principles for achieving excellent catalytic properties by control and manipulation of the composition and structure of solid catalysts made from abundant materials"

Project aims

- Develop novel catalyst technology completely eliminating critical metals
- Complete replacement critical metals in catalysts
- Focus on novel industrial processes based on renewable feedstocks

- Innovative and excellent science approach
  1) Catalysis by design
  2) Functional materials based on cheap and abundant metals
  3) Three labscale proof of concepts: biomass to fuels & chemicals

- Building scientific alliances between Japanese and EU researchers

- Dissemination of results through publications, networks, workshops

- Training young professionals in research

- Valorization & technology transfer research outcomes

NOVACAM: Conception

- Individual Japanese and EU researchers meet at conferences
- Visits to each other labs (e.g., prof. Nakajima visits Eindhoven in 2012)
- Shared interest in catalysis for renewables & “Catalysis by Design” approach

- Early 2012: exploration possibilities for collaboration
  identify partners in Japan and EU based on complementarity
- Aug. 2012: consultation industry on important scientific topics
  develop critical metal-free catalysts for renewables
  important biorefinery concepts:
  industrial advisory board:
  - Nippon Shokubai
  - Shell

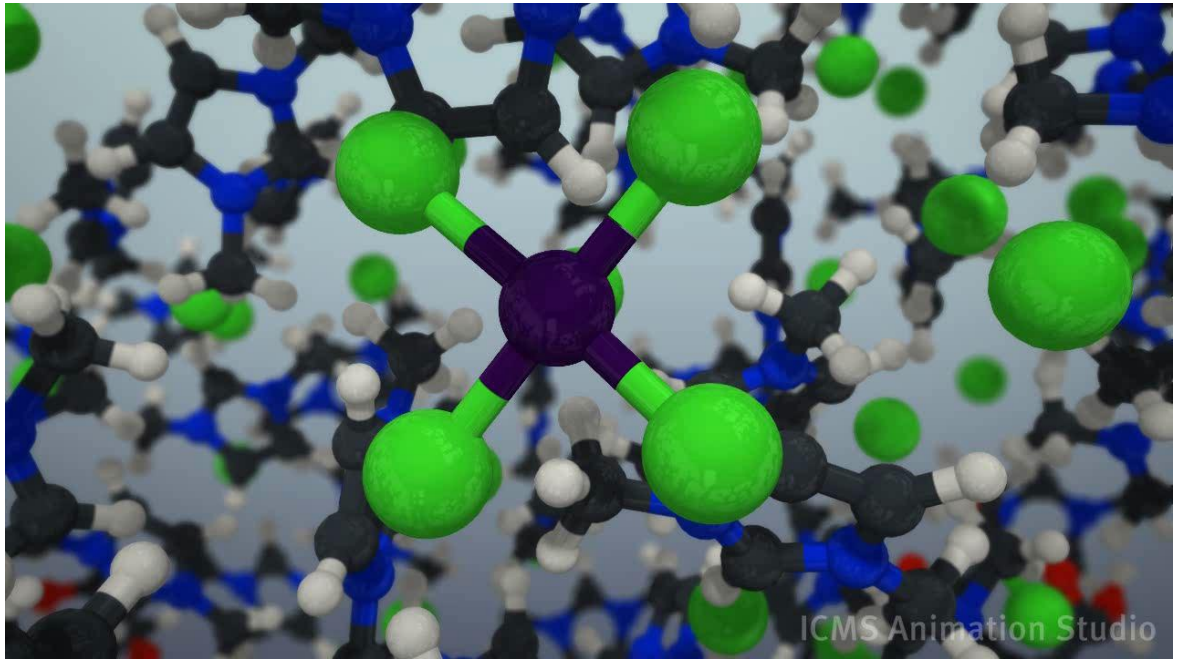
- **Valeric platform**
- **Synthetic glycolysis**
- **Aqueous-phase reforming**

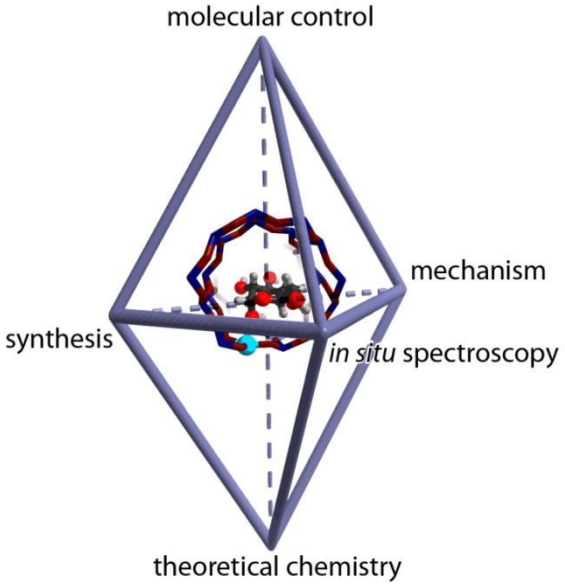
- Sept. 2012: definition main work packages & research approach

- Oct. 2012: consortium & cooperation agreement, finalize proposal

Catalysis by Design

Partners all follow modern '*Catalysis by Design*' approaches

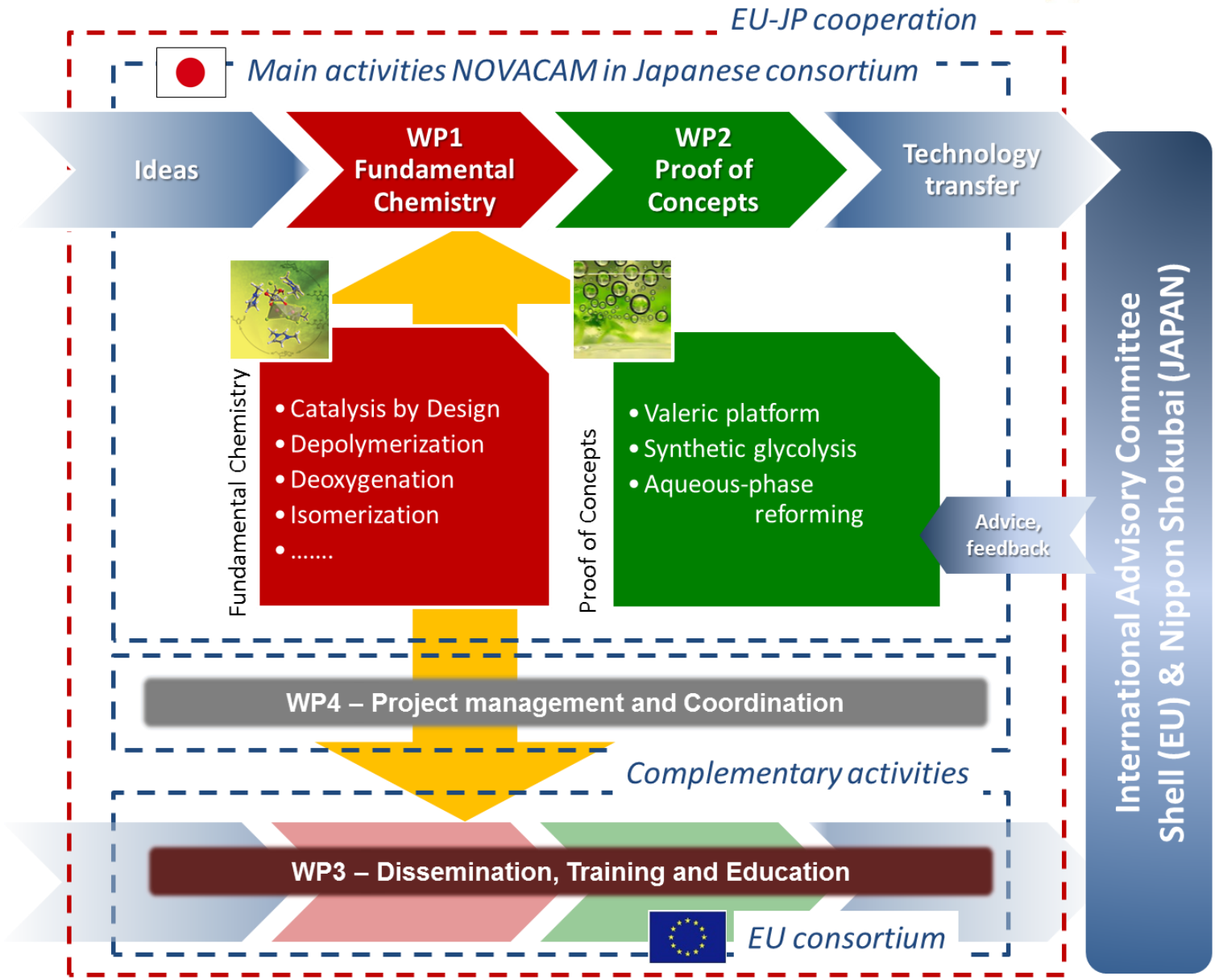




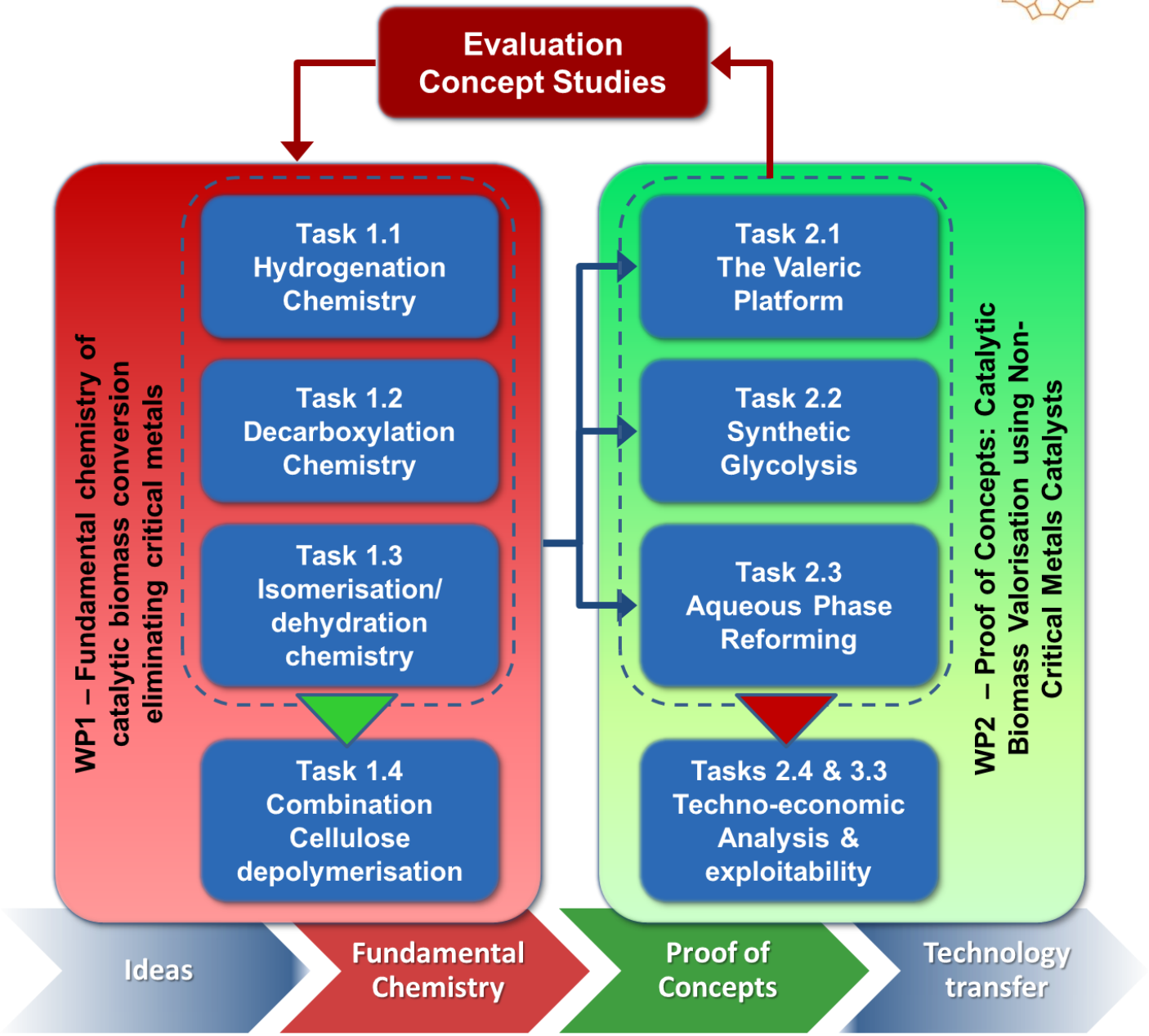
Sugar dehydration to platform molecules by alternative Lewis acid catalysts
Explored in groups of Hensen (EU) and Hara (Japan)

Hensen et al., Angew. Chem. In. Ed. 2010, 49, 2530
Hensen et al., Inorg. Chem. 2010, 49, 10081
Hensen et al., Chem. Eur. J. 2011, 17, 5281

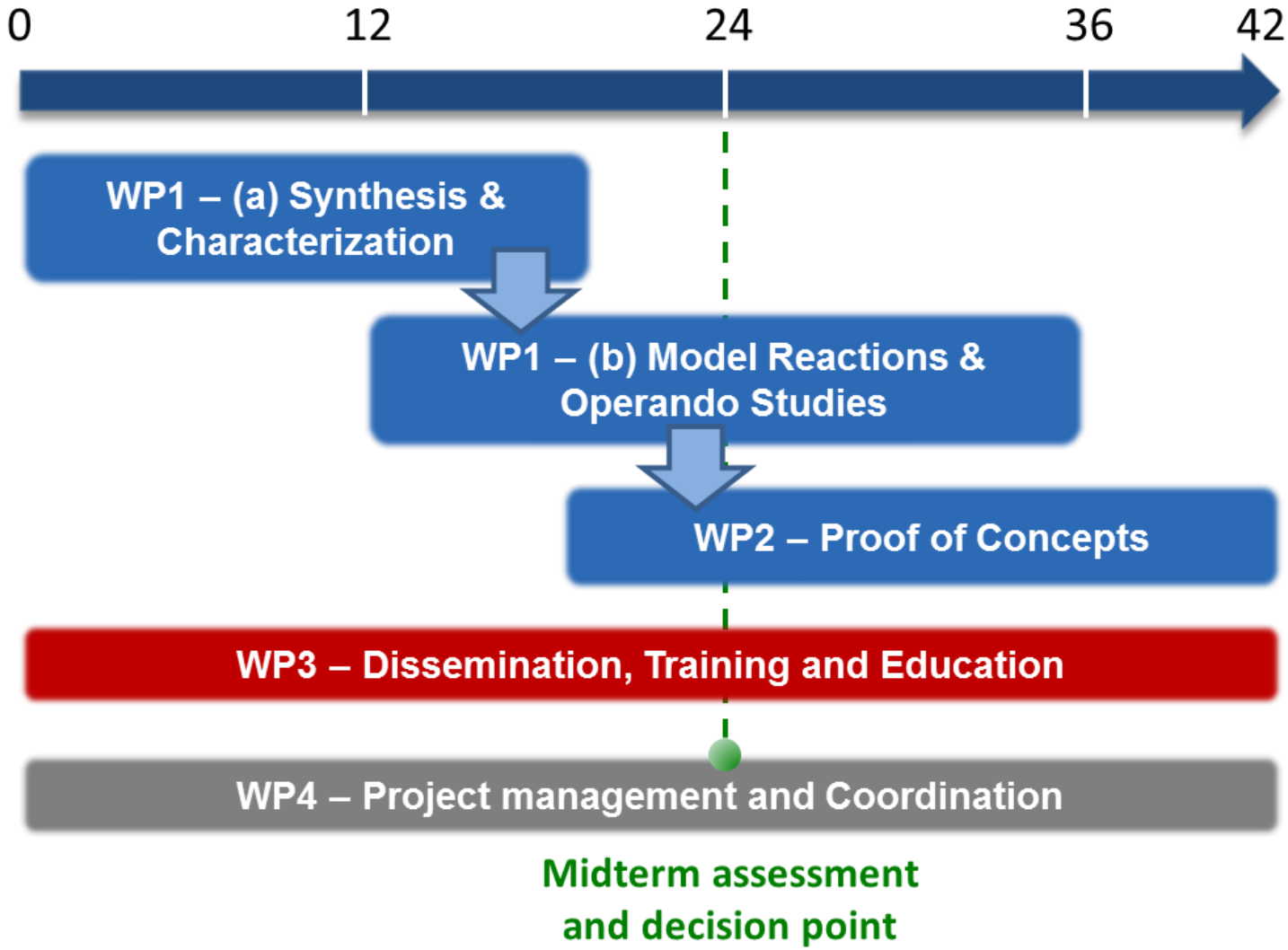
NOVACAM: overall project



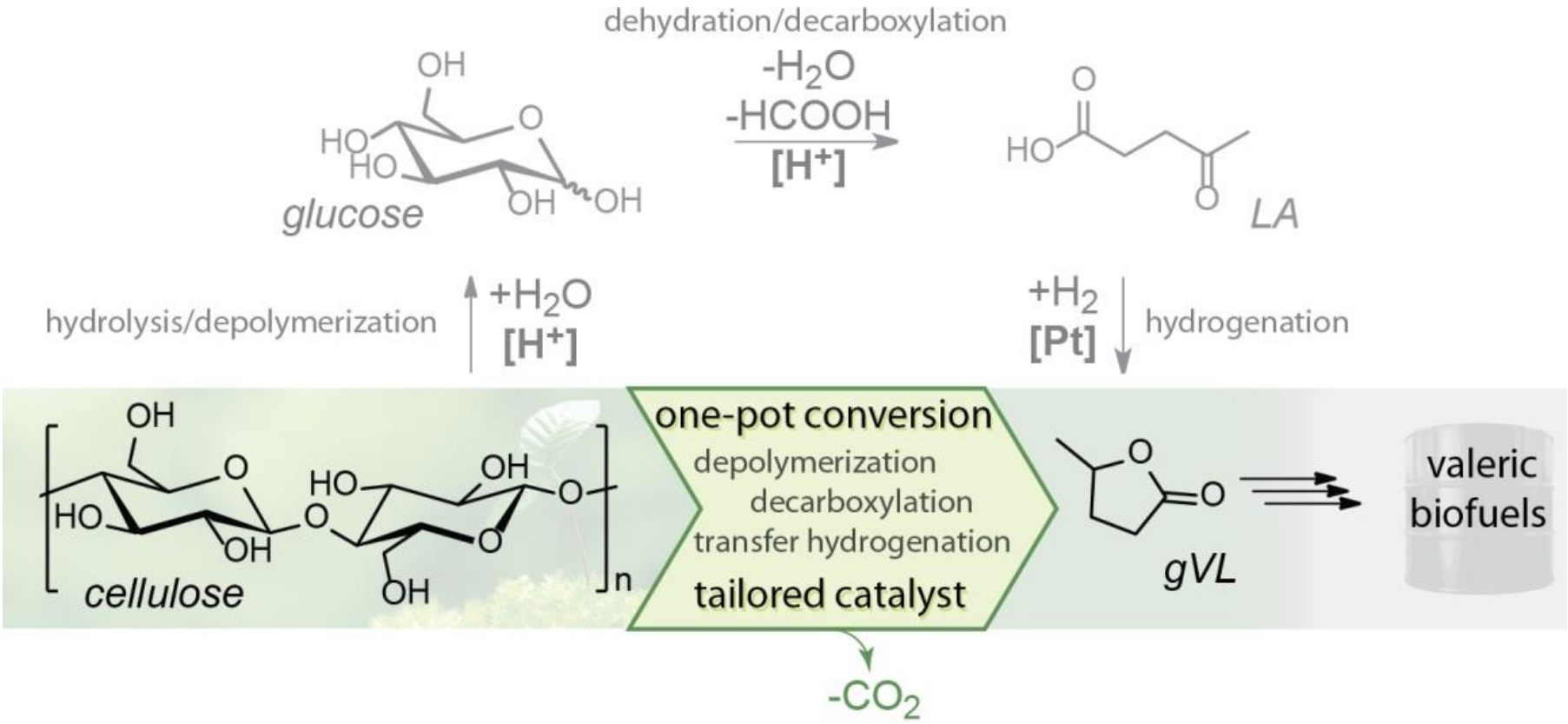
Research plan



Research plan (main WP)

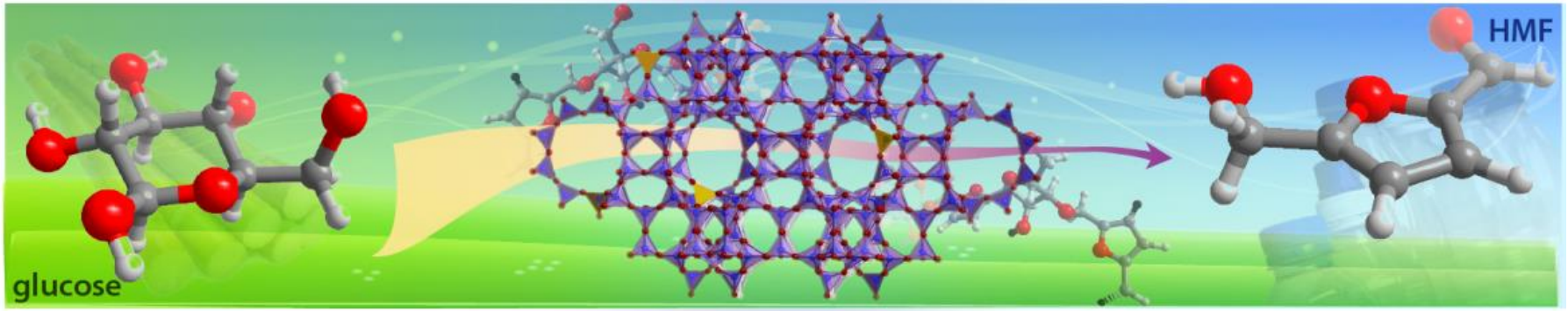


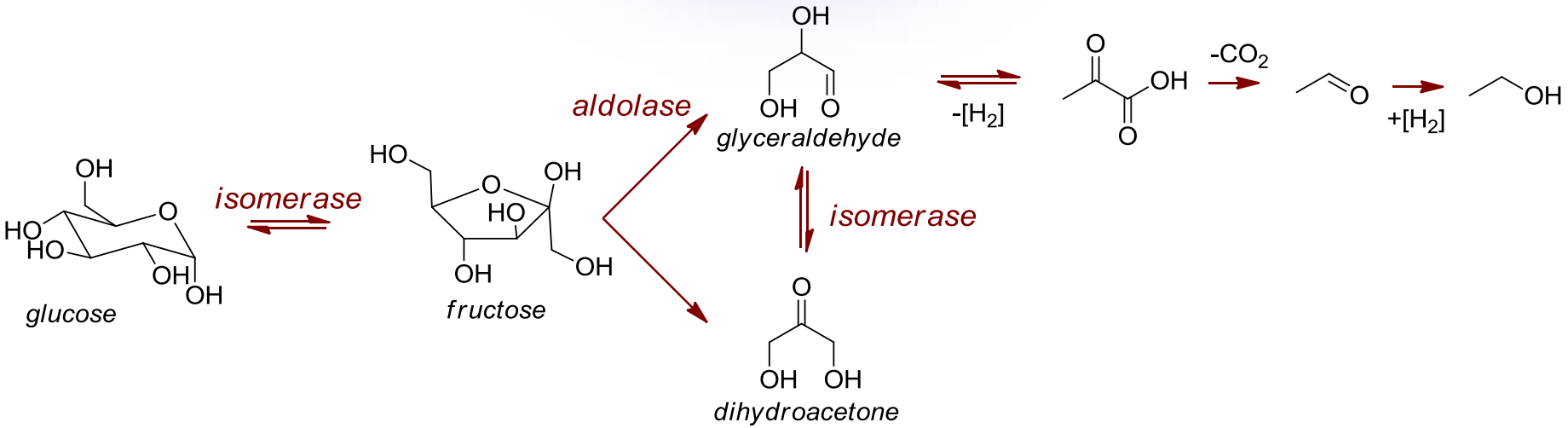
Research plan (line 1)



- Develop alternative ONE-STEP process without use of Pt
- Cheap fuels directly from cellulose
- Technology transfer to scale up such process

Research plan (line 2)





- Develop catalytic technology for glucose conversion to 5-HMF
- 5-HMF prime platform molecule in future biorefinery
- Development downstream technology to chemicals

Significant progress in glucose to ethanol conversion, replace biocatalytic process

Research plan (line 2)

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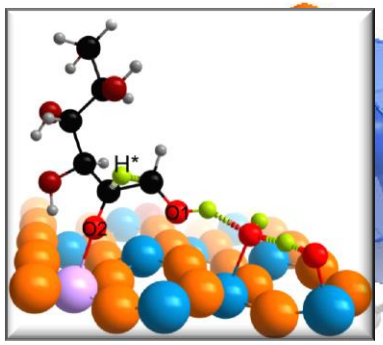
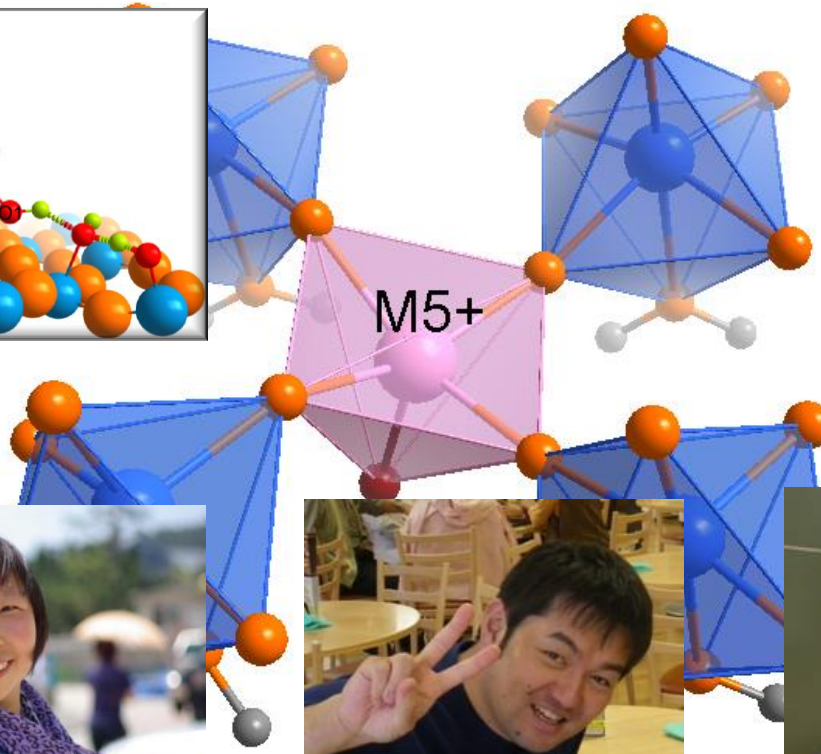
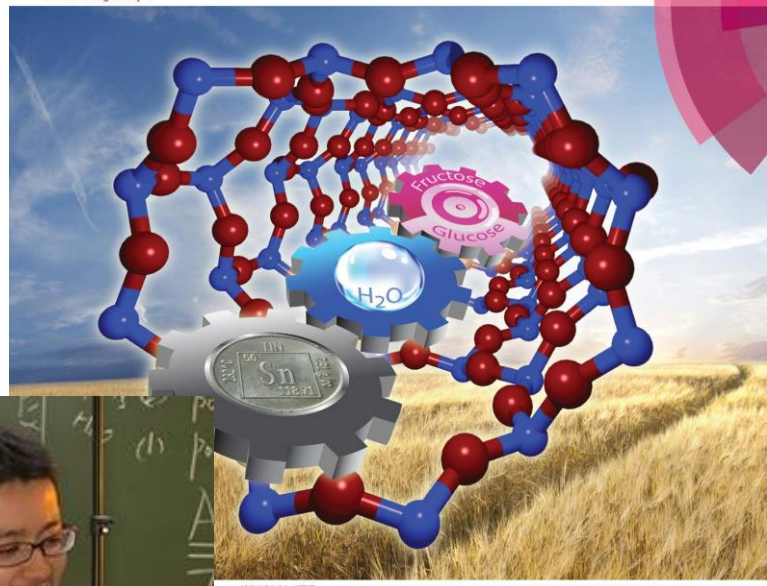
DFT calculations
Collaboration TU/e - TIT







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Catalysis Science & Technology
www.rsc.org/catalysis
ISSN 2044-4753
PAPER
Pidko et al
Synergy between Lewis acid sites and hydroxyl groups for the isomerization of glucose to fructose over Sn-containing zeolites a theoretical perspective

Dr. Guanna Li (TU/e) ***Dr. Kiyotaka Nakajima (TIT)*** ***Hiroshi Shintaku (TIT)***

Li, Pidko, Hensen, Catal. Sci. Technol. 2014, 4, 2241
Van der Graaff, Li, Mezari, Pidko, Hensen, ChemCatChem 2015, accepted

Consortium

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Knowledge Transfer Network

- Ideas
- Fundamental Chemistry
- Proof of Concepts
- Technology Transfer

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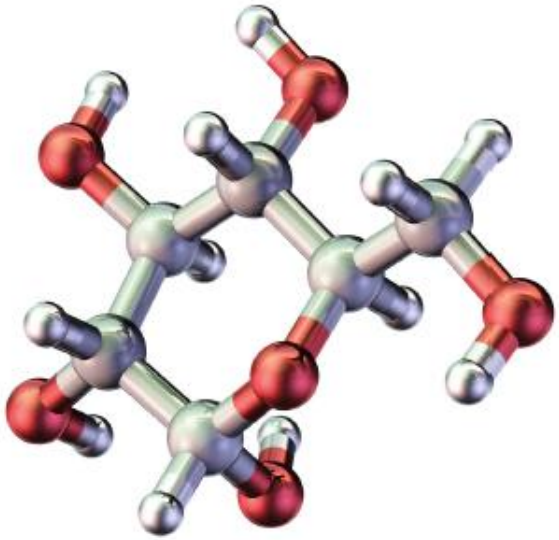
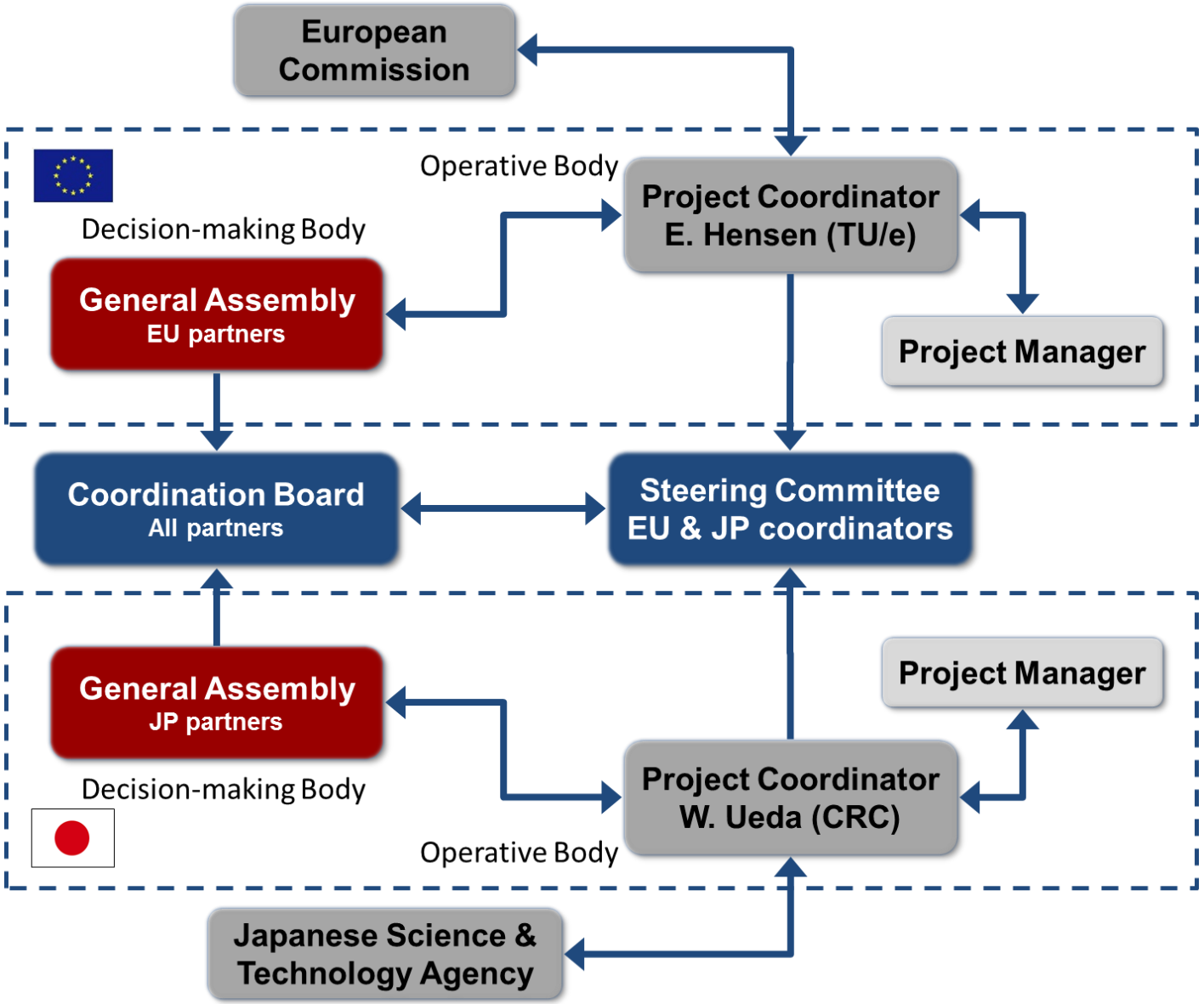
Developing catalysts using non-critical metals to unlock the potential of biomass

普遍触媒



www.novacam.eu
www.novacam.jp

Management & Reporting



Consortium

- Project coordinator Japan: W. Ueda (Hokkaido University)
- Project coordinator EU: E. Hensen (TU Eindhoven)

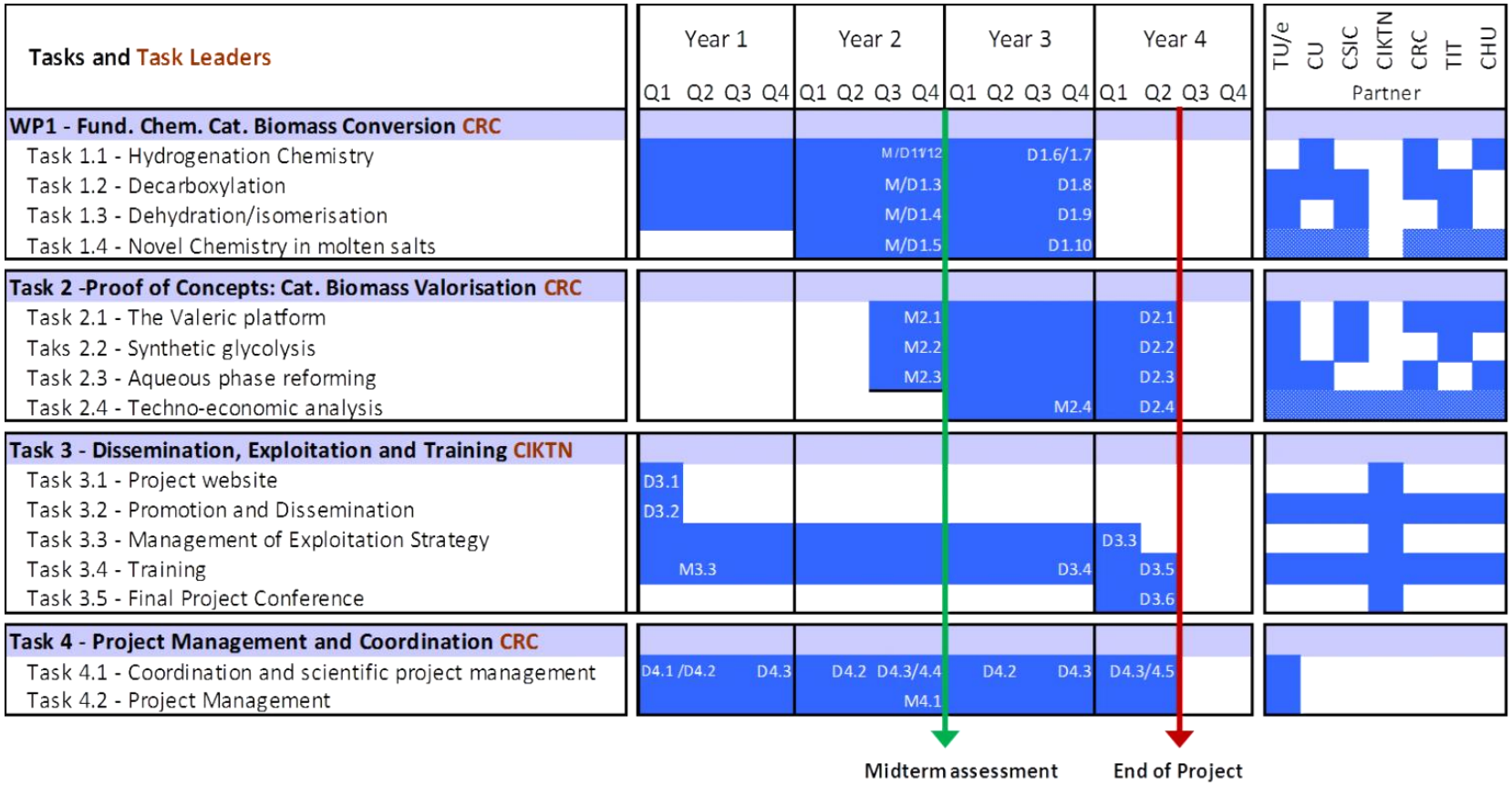
- Japan-EU interaction arranged in *cooperation agreement* including IPR

- Steering committee: project coordinators EU & Japan
  - Coordination and interaction between Japan & EU activities
  - Monthly contact between coordinators

- General assembly Japan (similar in EU)
  - Decision body of project
  - Technical, financial, exploitation planning
  - Two meetings per year, one consortium-wide (alternating Japan/EU)

- Industrial advisory board
  - Shell (EU) & Nippon Shokubai (Japan)
  - Advisory capacity on technical and technology transfer issues
  - Present at joint Japan-EU meetings
  - Identify opportunities valorization research outcomes/IP transfer

Role of partners



- WP and tasks carried out in integrated manner between all groups
- Separate WP for dissemination, exploitation and training headed by CIKTN
- Appointment of young researchers / exchange young researchers Japan-EU

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NOVel cheap and Abundant Materials for catalytic biomass conversion

Strengths & Opportunities

- Excellent research teams at Japanese and EU side
- Focussed effort to replace critical metals in catalysts
- Consortium supported by two major industries in Japan and EU
- Involvement of Knowledge Transfer Network for dissiminenation
- Clear coordination structure, intensive collaboration Japan/EU

Future prospect

- Towards strategic alliances between Japan and EU researchers
- Involve broader catalysis networks in Japan/EU in workshops
- Educate young academic and industrial professional with broad int'l view

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