



SAMPLE LANDSCAPE STUDY-

5-HYDROXYMETHYL FURFURAL (HMF)



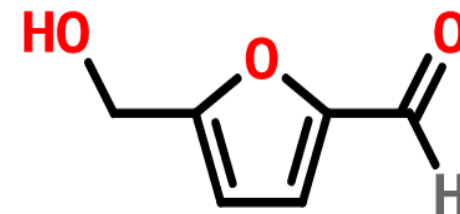
- Introduction to HMF and Applications
- Growth Prospects of Renewable HMF
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Introduction to HMF and Applications

What is HMF?

HMF is an organic compound consisting of a furan ring, containing both aldehyde and alcohol functional groups that can be derived from biomass and is a potential "carbon-neutral" feedstock for a number of chemical substances.

It can be referred as the most promising chemical compound that can replace the current dependence on fossil-fuel resources.



Applications

HMF is considered as the 'platform chemical' because of its usefulness in different industries in many applications including industrial production of polymers such as resins, bioplastics, pharmaceuticals, adhesives, paints etc.

Oxidized product of HMF such as 2,5-furandicarboxylic acid (FDCA), proposed as a better replacement for Terephthalic acid, precursor of polyester (PET).

HMF is used as an additive by the food and beverage industry

For sources of information, please refer to [Appendix 1](#)

Growth Prospects for Renewable HMF

- The global 5-Hydroxymethylfurfural (5-HMF) market is valued at 55867 K USD in 2018 and is expected to reach 62700 K USD by the end of 2025, growing at a CAGR of 1.45% between 2018 and 2025.
- Ava CO2 developed and patented water-based Hydrothermal Processing (HTP) technology, to convert C6 sugars into the bio-based platform chemical HMF.
- In 2013, AVA Biochem, a subsidiary of Ava CO2 begun operation of the world's first industrial plant for producing 5-HMF initially known to produce 20 tons/year of 5-HMF with a purity of up to 99.9% using biomass such as wood for feedstock.
- AVALON Industries AG, an entity of Swiss-based company Ava CO2 Schweiz AG founded in 2015, announced to take over all bio-based chemistry activities from Ava CO2 with immediate effect.
- The major players in global 5-Hydroxymethylfurfural (5-HMF) market include AVA Biochem , Robinson Brothers , Penta Manufacturer, NBB Company , Treatt , Beijing Lys Chemicals , Xuzhou Ruisai Technology and Wutong Aroma Chemicals.

For sources of information, please refer to [Appendix 1](#)

Objectives of the Landscape Study

- To understand technology and prepare patent landscape
- To understand major patent holders, geographical distribution of patents, top sub-technologies based on IPC codes
- Analysis of patent filing trends over the years, top assignees, top patent classifications, among others
- To conduct Patent Portfolio based study of patents relating to core focus area of HMF in the patents/ applications

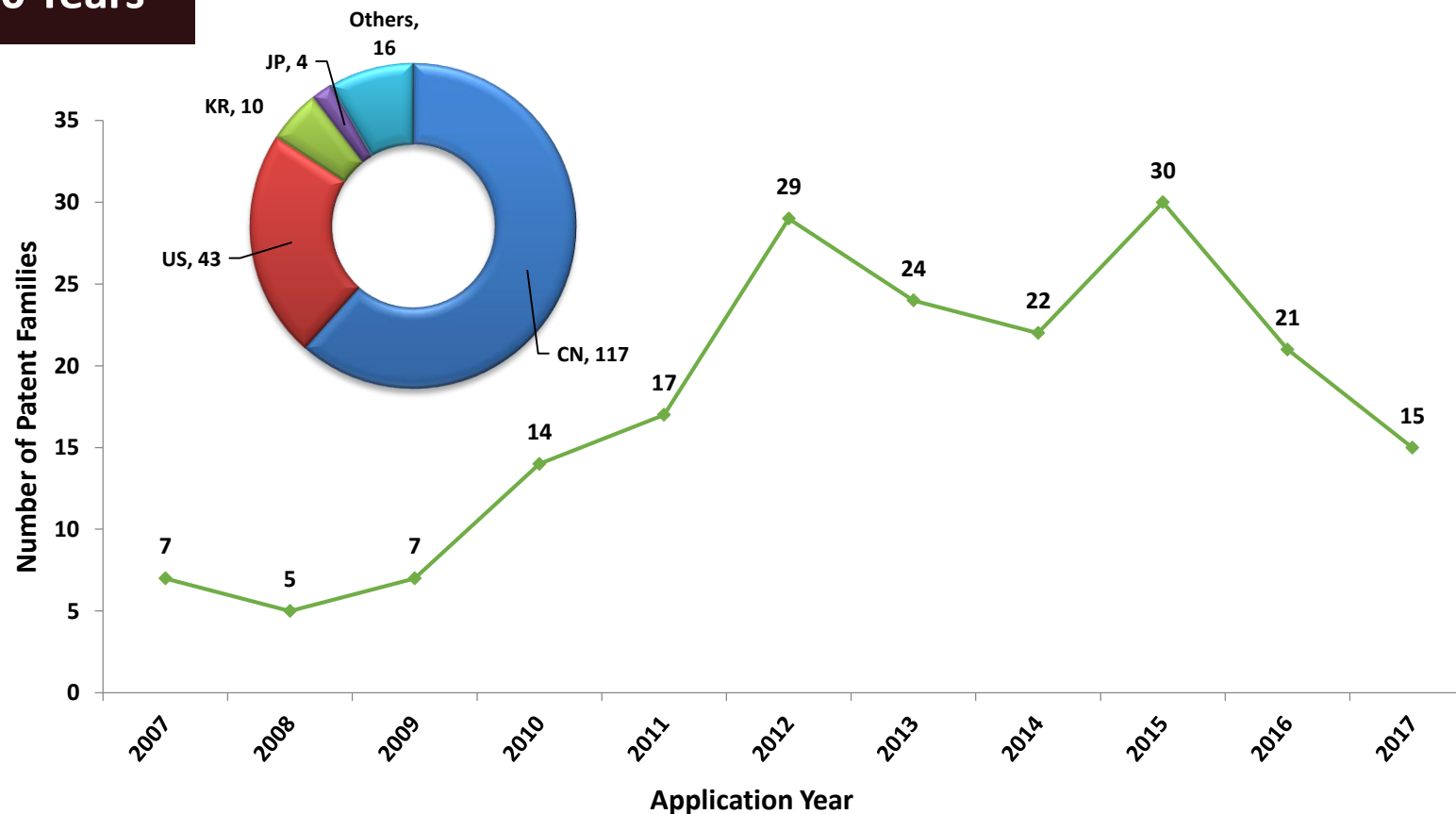
Assumptions:

- Report provides patent analysis for HMF market, which includes study of synthetic processes of HMF and advance technology based patents
- The landscape study focuses on patents pertaining to HMF published between **2008-2018**

For sources of information, please refer to [Appendix 1](#)

Trend Analysis and Graphical Representation

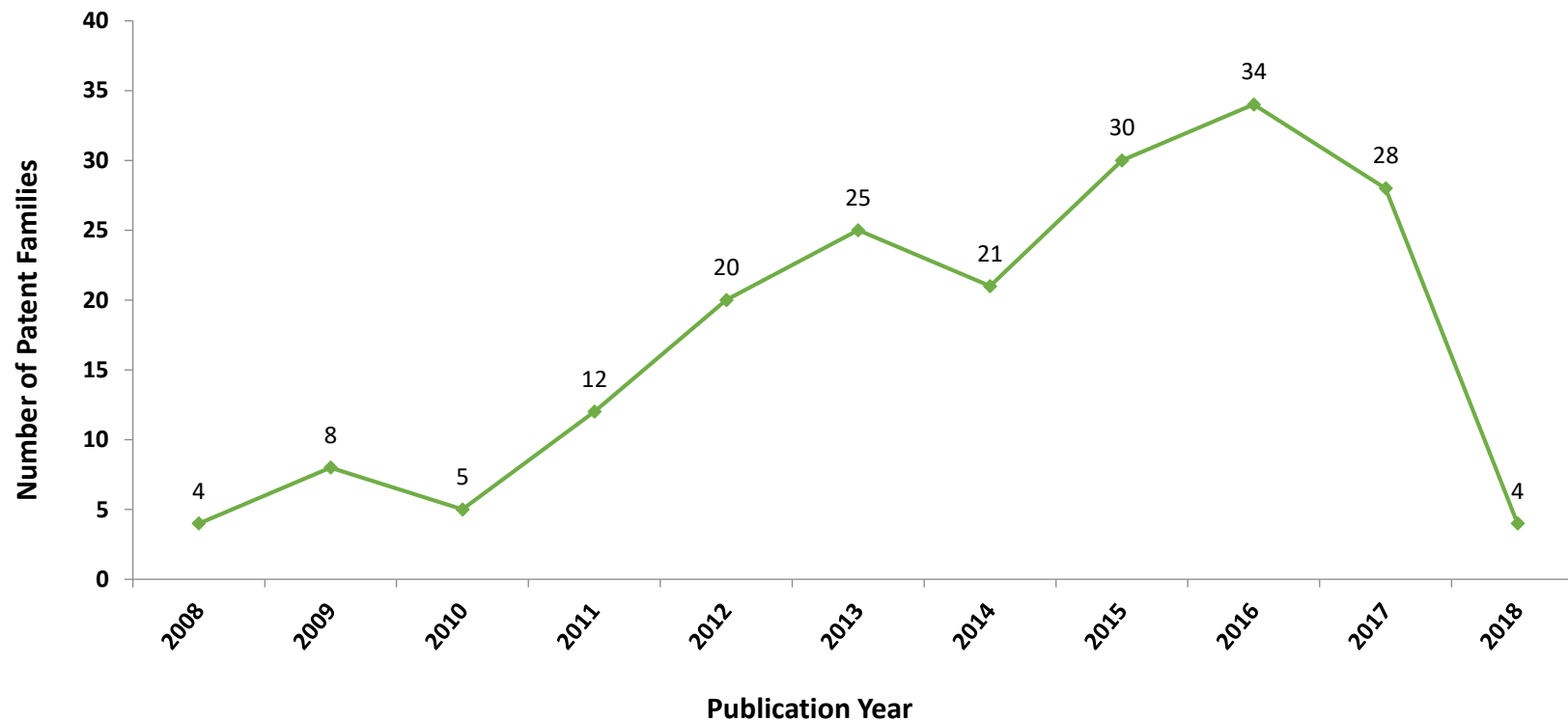
Filing Trends – Last 10 Years



Insight

Global patent filing trend analysis shows a consistent rise in the number of patent applications filed during year 2008-2012, followed by a dip in year 2013-2014. Highest rise was observed in the year from 2011-2012. Maximum number of applications were filed from CN, followed by US and KR jurisdictions.

Publication Trends - Last 10 Years

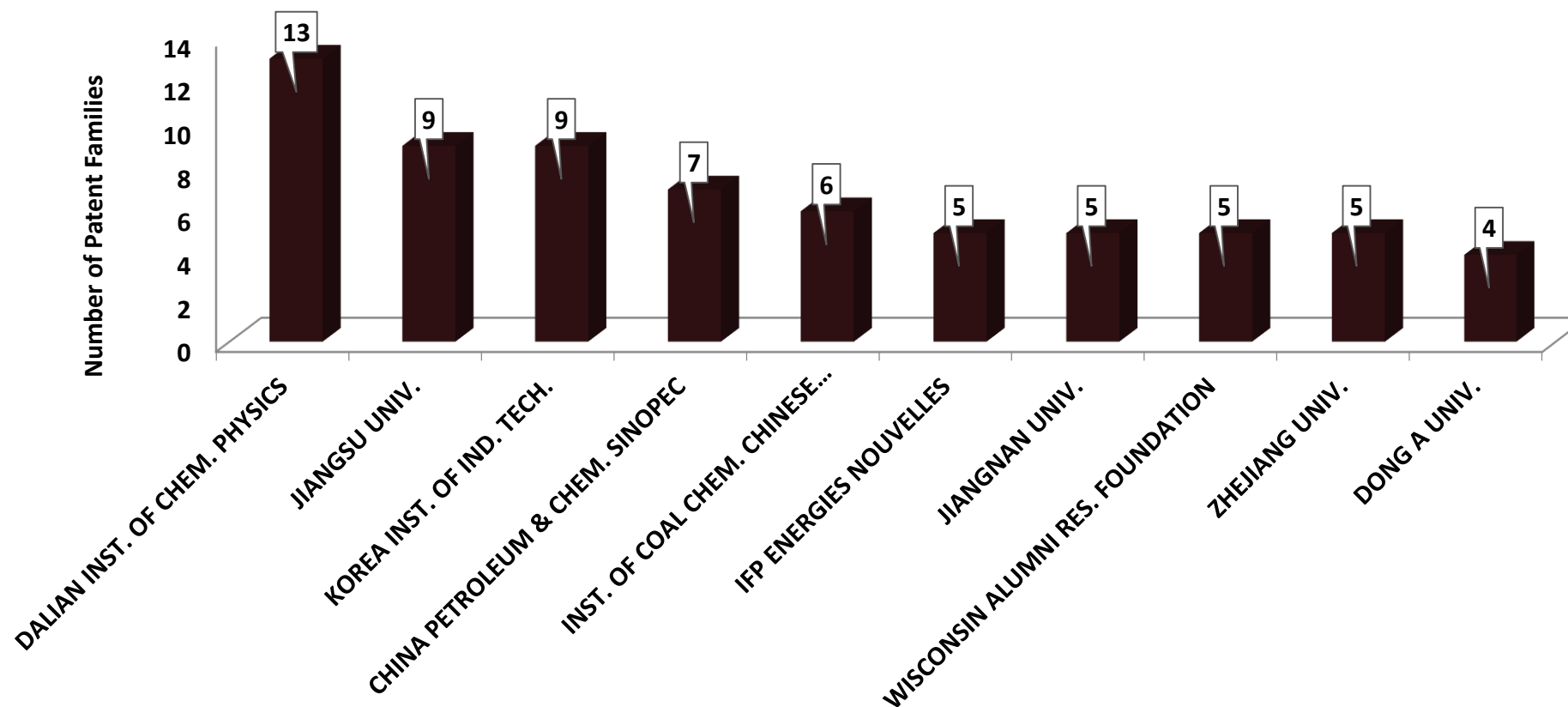


Insight

Global patent application publication trend presents a significant increase in the number of publication during last decade with its peak at 2016 which suggests significant filing during 2013-2015. Total number of patents published in 2018 may increase till the end of the year.

Graphs were prepared based on the analysis of application year for the priority country member

Top Assignees

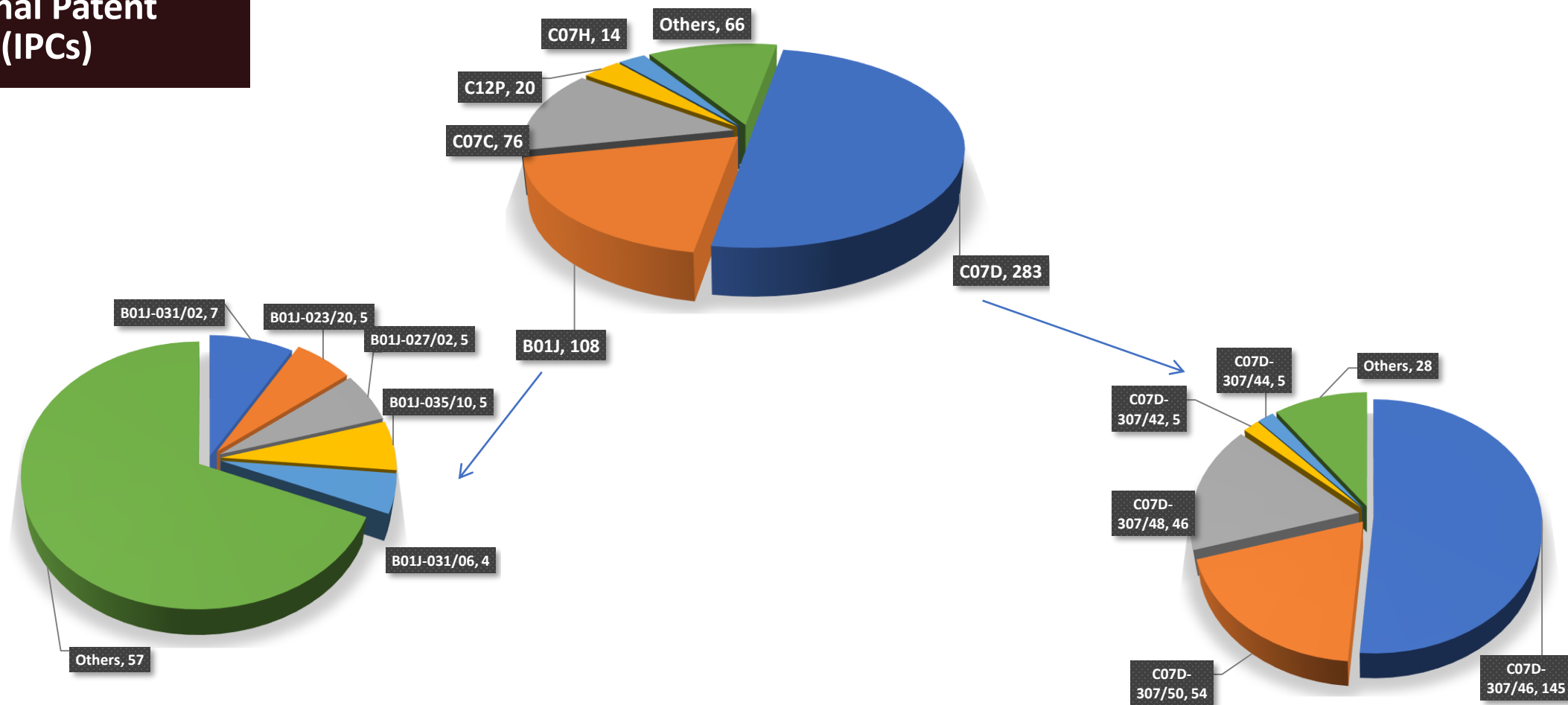


Insight

Dalian Institute is among leading patent filers in HMF Technology, followed by Jiangsu University and Korea Institute. Sinopac Group also has a significant patent portfolio.

Graph was prepared based on the analysis of application year for published applications (based on the representative family numbers)

Top International Patent Classifications (IPCs)

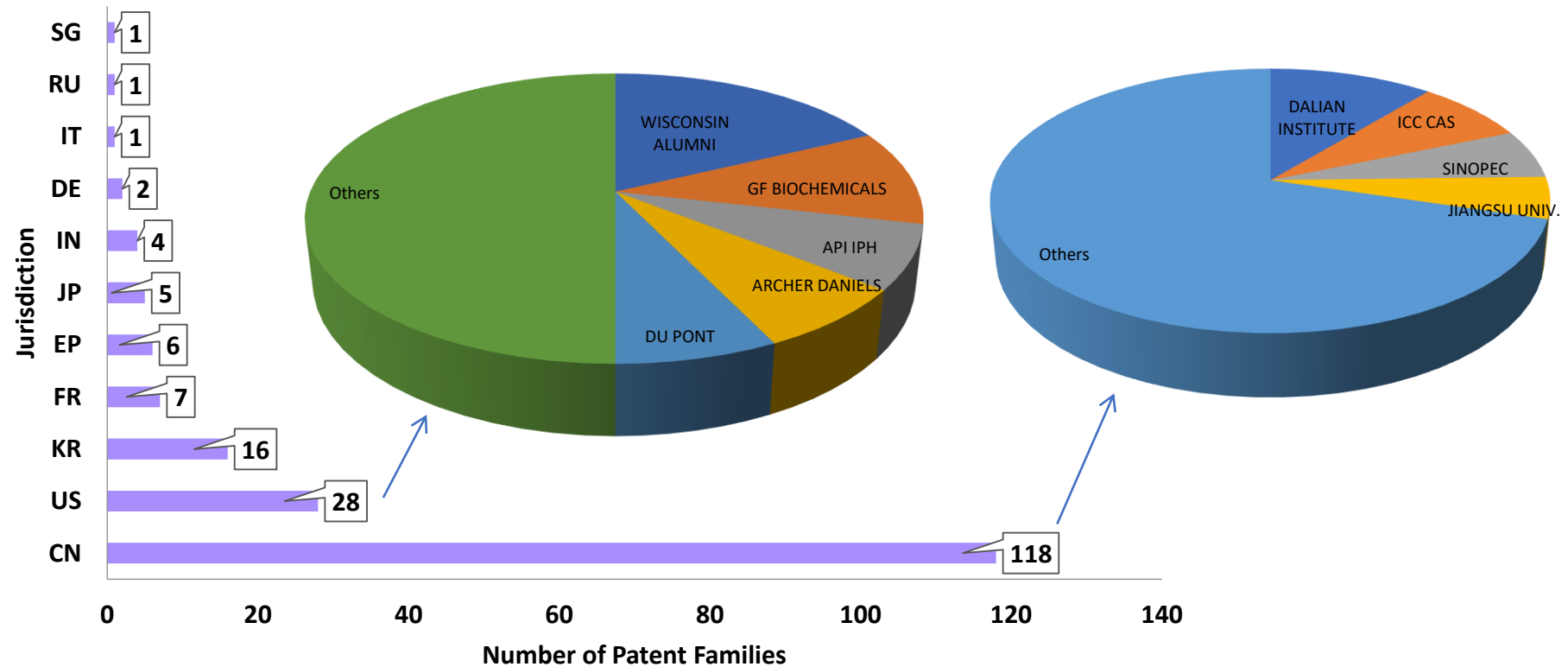


Insight

Maximum number of applications filed during 2007-2017 corresponds to IPC class C07D relating to '*Heterocyclic Compound*'. Amongst applications filed in C07D, majority of applications were filed in technology of sub-class C07D 307/46 which relates to '*five-membered rings having one oxygen atom as the only ring hetero atom and having doubly bound oxygen atoms, or two oxygen atoms singly bound to the same carbon atom*'. Second highest number of applications were filed in the technology covered by IPC class B01J which relates to '*Catalysis or colloid chemistry*'. Amongst applications filed in B01J, 10% of applications were filed in technology of sub-class B01J 31/02 which relates to the '*Catalysts comprising hydrides, coordination complexes or organic compounds; containing organic compounds or metal hydrides*'.

For IPC sub-class definitions please refer to [Appendix 2](#).

Geographic Origin of Innovation



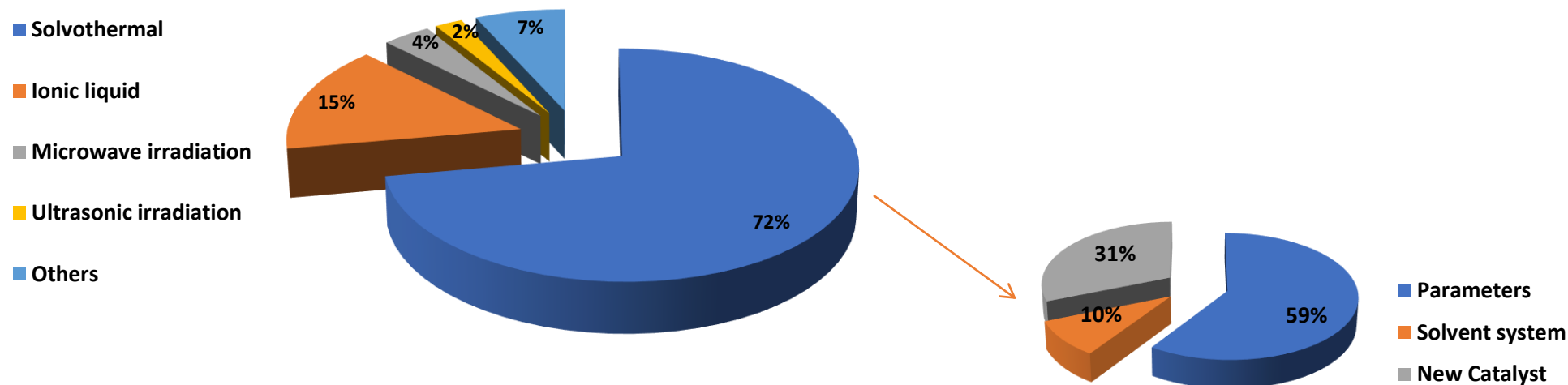
Insight

Analysis of Geographic Origin of Innovation demonstrates that maximum number of innovations originates from CN followed by US and KR jurisdictions. Dalian Institute contributes to maximum number of innovations originating from CN. Wisconsin Alumni and GF Biochemicals contributes to maximum number of innovations originating from US.

The graph representing Geographic origin of innovation was prepared based on the analysis of priority country

Key Technological Trends

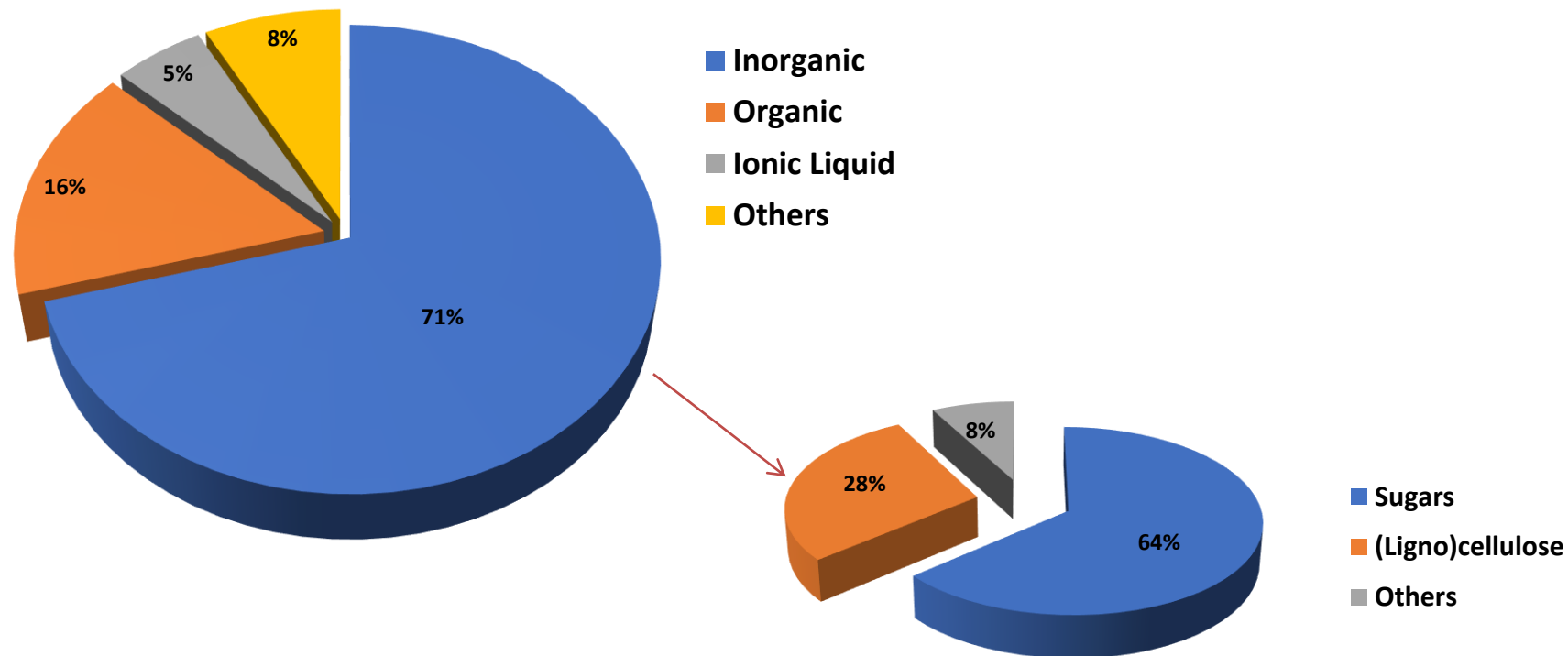
Process/Technology for HMF Production



Insight

Maximum percentage of applications (72%) were filed where HMF is produced solvothermally, followed by processes utilizing ionic liquid systems. China Petrochemical Corporation is the major player in the applications directed towards solvothermal production of HMF. Among solvothermal methods maximum applications were focused on altering reaction parameters followed introduction of new catalyst systems.

Catalyst System for HMF Production



Insight

Maximum percentage of applications (72%) were filed where HMF is produced solvothermally, followed by processes utilizing ionic liquid systems. China Petrochemical Corporation is the major player in the applications directed towards solvothermal production of HMF. Among solvothermal methods maximum applications were focused on altering reaction parameters followed introduction of new catalyst systems.

Patent Portfolio Analysis – AVALON (AVA CO2)

Hydrothermal Carbonization

- EP2681296A1
- DE102011001108B4
- WO2012119875A1

Biomass HMF Production

- DE102011053034

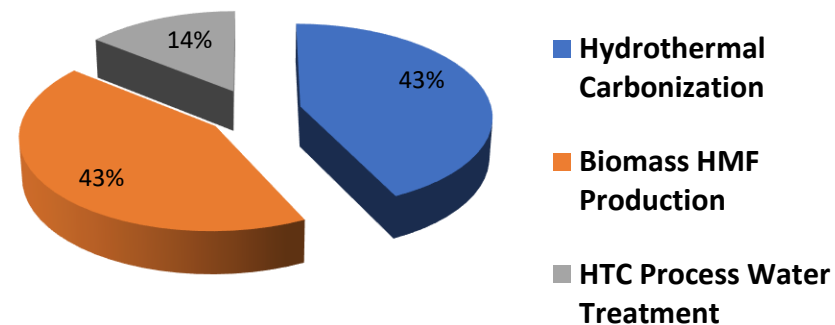
HTC Process Water Treatment

- US9416030B2
- EP2990385B1
- DE102014112240A1

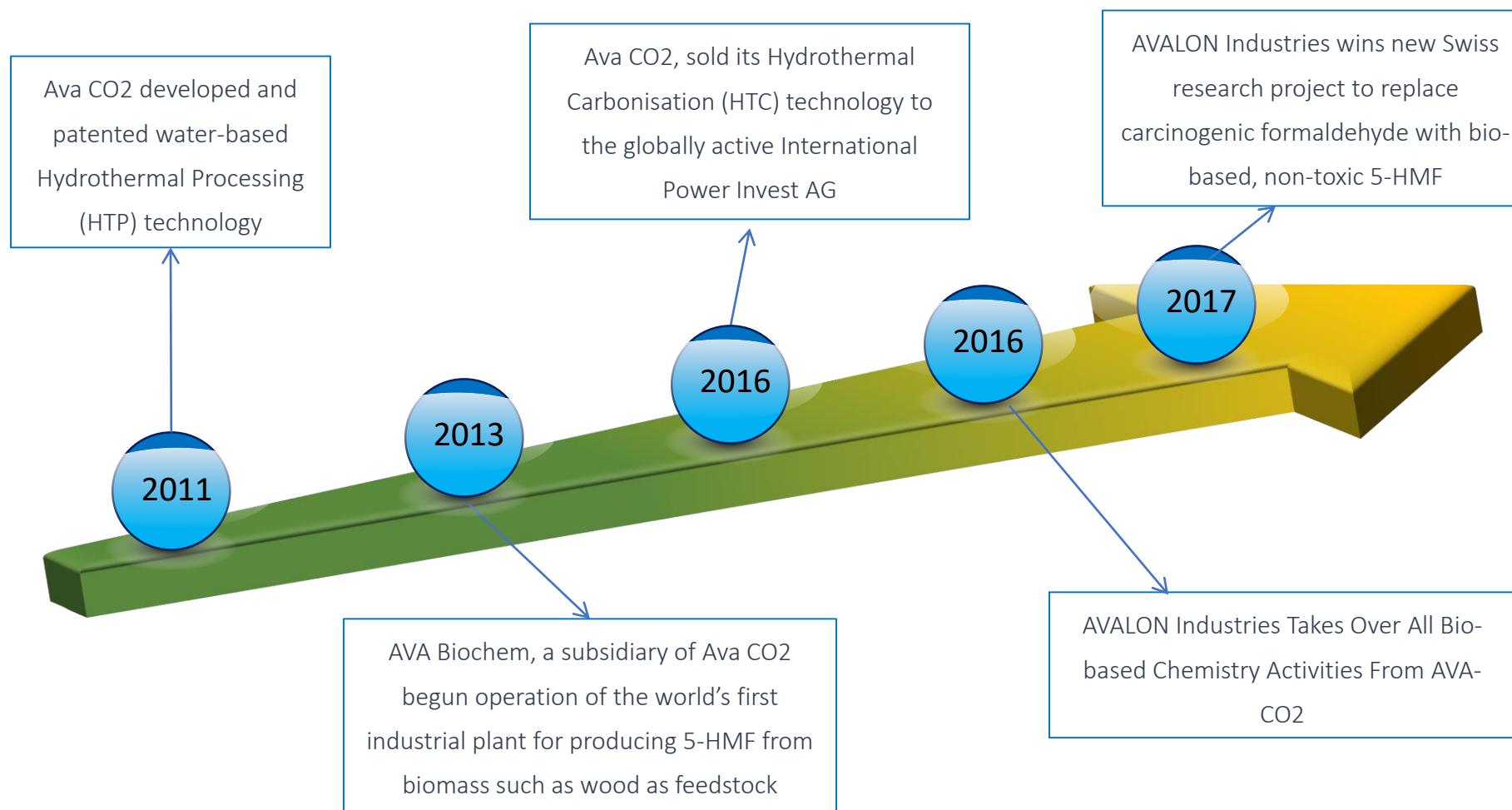
Company Profile

AVALON Industries is a trailblazer in sustainable, bio-based chemistry and global leader in the industrial production of bio-based platform chemical 5-Hydroxymethylfurfural (5-HMF). Since 2014, AVALON Industries' subsidiary AVA Biochem has been producing high-purity 5-HMF for the research and speciality chemicals markets.

Technological Dissection of Patent Portfolio



Key developments



For sources of information, please refer to [Appendix 1](#)

Patent Portfolio Analysis – AVALON (AVA CO2)

Key Patents:

Patent No.	Novel Features
DE102011053034	<p><u>A process for recovering furfurals, in particular of hydroxymethylfurfural (HMF) from biomass,</u> wherein a water and biomass (10) Containing slurry is heated in a reaction vessel and in this case (by conversion of the biomass 10) Arising HMF (17 Is obtained) or furfural to the conversion process by means of a separating method from the slurry, characterized in that it is <u>(in biomass_10) At least substantially is to lignocellulose,</u> which sequentially (in glucose, fructose and eventually HMF under heat 17) Or furfural is converted.</p>

Patent Portfolio Analysis – China Petrochemical Corporation (Sinopec Group)



New Process

- CN104557805
- CN104557806
- CN106146434
- CN106146435
- CN106146437
- CN106146436

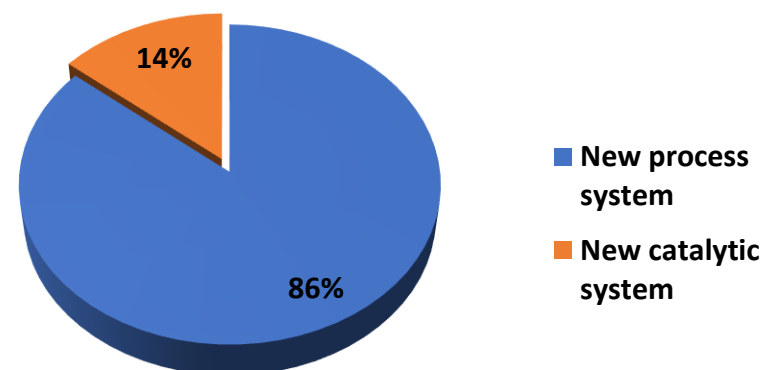
New Catalytic System

- CN105330623

Company Profile

China Petrochemical Corporation (Sinopec Group) is the largest oil and petrochemical products suppliers and the second major oil and gas producer in China. The principal operations of Sinopec Group include industrial investment and investment management; production, sale, storage and transportation of coal; oil refining.

Technological Dissection of Patent Portfolio



Patent Portfolio Analysis – China Petrochemical Corporation (Sinopec Group)



Key Patents:

Patent No.	Novel Features
CN104557805	A method relates to 5-hydroxymethyl furfural production technology, particularly to a static mixer <u>producing 5-hydroxymethyl furfural from biomass feedstock</u> as a process using a <u>reactor</u> .
CN105330623	Discloses an <u>inorganic salt catalytic synthesis method for 5-hydroxy methyl furfural</u> . The method comprises the steps that sugar used as a raw material and <u>inorganic salt (NaCl, KCl, ZnCl₂)</u> used as a catalyst in an organic solvent. The mole ratio of the sugar to the inorganic salt is 2:1, the heating temperature in the reaction process is controlled to 100-120 DEG C. The heating source for the reaction is <u>microwave irradiation</u> .

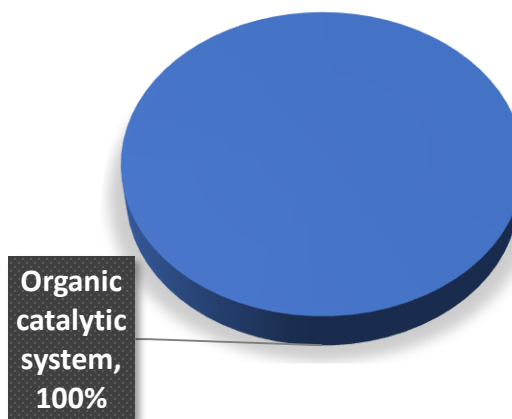
Organic Catalytic System

- WO201716924
- WO201716925
- WO201716923
- WO201776625
- WO201776626

Company Profile

IFP Energies nouvelles (IFPEN) is a major researcher in the fields of energy, transport and the environment. It conducts research on various themes, including renewable energies, eco-friendly production, innovative transport, eco-efficient processes, and sustainable resources.

Technological Dissection of Patent Portfolio



Key Patents:

Patent No.	Novel Features
WO201776626	A process for producing 5-hydroxymethylfurfural from a feedstock comprising at least one sugar using a combination of at least one catalyst selected from <u>homogeneous Lewis acids, heterogeneous Lewis acids, and heterogeneous bases</u> and at least one homogeneous Bronsted acid catalyst selected from the families of thioureas, sulfonic acids and organic phosphorus compounds alone or in admixture in the presence of at least <u>one aprotic polar solvent</u> at a temperature between 30 ° C and 300 ° C, and a pressure between 0.1 MPa and 10 MPa.
WO201716925	A method of converting a feed comprising at least one sugar 5- hydroxymethylfurfural, wherein said filler is contacted with one or more <u>organic catalysts</u> in the presence of at least one solvent, <u>said solvent being water or an organic solvent alone or mixed</u> , at a temperature between 30 ° C and 200 ° C, and at a pressure between 0.1 MPa and 10 MPa wherein said one or <u>more organic catalysts</u> are selected from <u>sulfonamides</u> compounds

Analysis of Key Granted Patent Assigned to Educational Institutes and Universities

Granted Patents Analysis – Institutes & Universities

Patent No.	Novel Features
CN101456851 (DALIAN INSTITUTE OF CHEMICAL PHYSICS)	<p>1. The method of preparing 5-hydroxymethylfurfural 1. <u>A microwave irradiation</u>, characterized in that: 1) was dissolved preheating: <u>ionic liquid as a reaction medium</u>, to hexose or hexose source substrate biomass as a feedstock, the and mixing the reaction medium is heated and dissolved material substrate; wherein the ionic liquid is a raw material of the substrate has a good ability to dissolve the ionic liquid, the <u>ionic liquid is a compound of formula I and formula any structure ...</u></p>
CN103172599 (DALIAN INSTITUTE OF CHEMICAL PHYSICS)	<p>1. Catalytic process for preparing 5-hydroxymethylfurfural and levulinic acid carbohydrates, characterized in that: <u>tungsten and tantalum which is a composite or mixed oxide as catalyst</u>, carbohydrate raw materials, at a temperature of 80-300 V reacting, under liquid phase conditions catalyzes the carbohydrate to form 5-hydroxymethyl furfural (of HMF) and levulinic acid (LA), LA yield up to 40% -95%; and tungsten trioxide to pentoxide meter tantalum, tungsten oxide catalyst tantalum oxide ratio of 0.5 to 20 mass%.</p>
US9206148 (KOREA INSTITUTE OF INDUSTRIAL TECHNOLOGY)	<p>1. <u>A method for producing 5-hydroxymethyl-2-furfural (HMF) from maize syrup containing fructose</u>, wherein the 5-hydroxymethyl-2-furfural is expressed by chemical formula: and the method comprises a conversion step in which a reactant containing the 5-hydroxymethyl-2-furfural is produced by <u>mixing and heating the maize syrup, a dioxane solvent, and a solid acid catalyst, wherein the solid acid catalyst is a cation exchange resin.</u></p>

Granted Patents Analysis – Institutes & Universities

Patent No.	Novel Features
US9206147 (KOREA INSTITUTE OF INDUSTRIAL TECHNOLOGY)	1. A method of producing a furan-based compound, comprising <u>reacting an aldose-type hexose compound in the presence of an anion exchange resin and a cation exchange resin</u> in the presence of an organic solvent.
CN103121984 (INSTITUTE OF COAL CHEMISTRY CAS)	1. <u>By using a chitin-based biomass</u> production 5-hydroxymethyl furfural method, characterized in comprising the steps of:(1) formulating a mass concentration of <u>30%-72% of the zinc chloride aqueous solution</u> , the dried chitin-based biomass feedstock, zinc chloride aqueous solution and catalyst are mixed uniformly, at 60 °C -140 °C under 10 minutes reaction-10 hours, wherein: chitin-based biomass feedstock with aqueous zinc chloride mass ratio of 1:3-180, ...
US8772515 (WISCONSIN ALUMNI RESEARCH FOUNDATION)	1. A process to produce 5-hydroxymethylfurfural (HMF), the process comprising: reacting a C6 sugar-containing reactant in a monophasic reaction solution comprising (i) <u>an organic solvent selected from the group consisting of beta-, gamma-, and delta-lactones, hydrofurans, hydropyrans, and combinations thereof</u> , and (ii) at least about 1 wt % water; in the presence of a heterogenous acid catalyst for a time and under conditions wherein at least a portion of the C6 sugar present in the reactant is converted to HMF.

Granted Patents Analysis – Institutes & Universities

Patent No.	Novel Features
US8680264 (WISCONSIN ALUMNI RESEARCH FOUNDATION)	1. A method for converting a carbohydrate to a furan which comprises the steps of: (a) preparing a mixture of the carbohydrate in a <u>polar aprotic solvent containing a chromium halide</u> ; and (b) heating the mixture to obtain a furan, wherein the carbohydrate is a lignocellulosic feedstock and the <u>polar aprotic solvent is an ionic liquid</u> .
CN102993140 (ZHEJIANG UNIVERSITY)	1. A catalytic conversion of biomass production 5-hydroxymethyl furfural method, characterized in, comprises the following steps: To fructose, glucose, sucrose, cellobiose or cellulose as a reaction substrate, at a <u>super-hydrophobic solid acid as a catalyst, using tetrahydrofuran, dimethyl sulfoxide, chlorinated 1-ethyl-3-methylimidzo ionic liquid or chlorinated 1-butyl-3-methylimidzo ionic liquid as a reaction solvent</u> ; the reaction substrate is added to the reaction solvent, the reaction system temperature was raised to 80-150 °C after, adding a catalyst and tin tetrachloride, the reaction was continued time 2-10 hours;...
KR101375247 (DONG A UNIVERSITY)	1. <u>Process for producing a hydroxymethyl-furfural with orange peel</u> comprising the steps of: (a) powdering the dried orange peel; (B) an aqueous solution of the orange peel powder HCl; [OMIM] Cl; [OMIM] Cl and a mixture of ethyl acetate (EA); [OMIM] a mixture of HCl and Cl; [OMIM] Cl, were added to the ionic liquid selected from the group consisting of a mixed solution of HCl and ethyl acetate were reacted at 110 °C to 150 °C for 10 hours to 20 hours to afford a hydroxymethyl furfural;

Granted Patents Analysis – Other Companies

Patent No.	Novel Features
US9260402 (BASF)	1. A process for the preparation of 5-hydroxymethylfurfural (HMF), having the following steps: (a) providing or preparing a starting mixture, comprising (i) one, two or more starting compounds selected from the group consisting of hexoses, oligosaccharides comprising hexose units, and polysaccharides comprising hexose units, (ii) <u>one, two or more organic salts having a melting point <180 deg. C. and a boiling point >200 deg. C. at 1013.25 hPa,</u>
US8524924 (DU PONT)	1. A process for the selective production of furfural, the process comprising the steps of: a) providing a lignocellulosic feedstock comprising glucan and xylan; b) contacting the feedstock with water in the presence of an acid catalyst to form a mixture; c) contacting the mixture formed in step b) <u>with at least one water-immiscible organic solvent in a reactor and heating to a temperature from about 100 deg. C. to about 220 deg. C. to form a mixture comprising an aqueous phase and a furfural-containing organic phase</u> , wherein the organic solvent and water are present in a weight ratio in the range of 7.7:1 to 32.1:1, ...
US9637463 (MICROMIDAS)	1. A method for producing a hydroxymethylfurfural <u>in a gas-solid phase reactor</u> , the method comprising: feeding solid feedstock into a gas-solid phase reactor, wherein the solid feedstock comprises biomass or sugar, or any combination thereof; ...

Granted Patents Analysis – Other Companies

Patent No.	Novel Features
US9409877 (NOVAMONT)	1. A process for preparing 5-hydroxymethylfurfural comprising the steps of: A) heating at a temperature from 60 deg. C. to 120 deg. C. for a time from 10 minutes to 12 hours a reaction mixture consisting of: a) <u>a quaternary ammonium salt R₃R'⁺N⁺X⁻ wherein: R, which is the same or different, is a C1-C4 alkyl group; R' is a C1-C15 alkyl group; X⁻ is an anion selected from chloride, bromide, iodide, fluoride, and hydroxide;</u>
US8697893 (SARTEC)	1. A method of producing 5-hydroxymethylfurfural (HMF), comprising: <u>contacting cellulose with a metal oxide catalyst at a temperature between about 260 and about 280 degrees Celsius to produce the 5-hydroxymethylfurfural (HMF) in a single reaction step wherein the metal oxide catalyst is selected from the group consisting of alumina, hafnia, titania, zirconia, and mixtures thereof.</u>

APPENDIX 1: Sources

- <https://pubs.acs.org/doi/abs/10.1021/cr300182k>
- <http://specchem.businesscatalyst.com/featuredarticles/biobased-5-hmf-a-versatile-platform-chemical>
- <https://marketersmedia.com/global-5-hydroxymethylfurfural-5-hmf-market-is-valued-at-55867-k-usd-in-2018-expected-to-reach-62700-k-usd-end-of-2025/324478>
- <https://greenchemicalsblog.com/2013/07/01/worlds-first-5-hmf-industrial-facility/>
- <http://news.bio-based.eu/avalon-industries-wins-new-swiss-research-project-to-replace-carcinogenic-formaldehyde-with-bio-based-non-toxic-5-hmf/>
- <https://www.sustainabilityconsult.com/news/229-press-release-avalon-industries-takes-over-all-bio-based-chemistry-activities-from-ava-co2>
- <http://www.avalon-industries.com/web/pages/en/home.php>
- <http://www.sinopecgroup.com/group/en/companyprofile/AboutSinopecGroup/>
- <http://www.ifpenergiesnouvelles.com/IFPEN/In-brief>
- <https://www.sciencedirect.com/science/article/pii/S0920586112003550>

APPENDIX 2: Definition Of IPC Classes

IPC Class	Definitions
C07D	Chemistry; Metallurgy; Organic Chemistry; Heterocyclic Compounds
C07D 307/46	Chemistry; Metallurgy; Organic Chemistry; Heterocyclic Compounds; Heterocyclic compounds containing five-membered rings having one oxygen atom as the only ring hetero atom; not condensed with other rings; having two or three double bonds between ring members or between ring members and non-ring members; with substituted hydrocarbon radicals attached to ring carbon atoms; Doubly bound oxygen atoms, or two oxygen atoms singly bound to the same carbon atom
C07D 307/48	Chemistry; Metallurgy; Organic Chemistry; Heterocyclic Compounds; Heterocyclic compounds containing five-membered rings having one oxygen atom as the only ring hetero atom; not condensed with other rings; having two or three double bonds between ring members or between ring members and non-ring members; with substituted hydrocarbon radicals attached to ring carbon atoms; Doubly bound oxygen atoms, or two oxygen atoms singly bound to the same carbon atom; Furfural
C07D 307/50	Chemistry; Metallurgy; Organic Chemistry; Heterocyclic Compounds; Heterocyclic compounds containing five-membered rings having one oxygen atom as the only ring hetero atom; not condensed with other rings; having two or three double bonds between ring members or between ring members and non-ring members; with substituted hydrocarbon radicals attached to ring carbon atoms; Doubly bound oxygen atoms, or two oxygen atoms singly bound to the same carbon atom; Furfural; Preparation from natural products
B01J	Performing operations; transporting; separating; mixing; physical or chemical processes or apparatus in general; chemical or physical processes, e.g. Catalysis or colloid chemistry; their relevant apparatus
B01J 23/20	Performing operations; transporting; separating; mixing; physical or chemical processes or apparatus in general; chemical or physical processes, e.g. Catalysis or colloid chemistry; their relevant apparatus, Catalysts comprising metals or metal oxides or hydroxides; of arsenic, antimony, bismuth, vanadium, niobium, tantalum, polonium, chromium, molybdenum, tungsten, manganese, technetium or rhenium; Vanadium, niobium or tantalum
B01J 31/02	Performing Operations; Transporting; Separating; Mixing; Physical or Chemical Processes or Apparatus In General; Chemical or Physical Processes, e.g. Catalysis or Colloid Chemistry; Their Relevant Apparatus; Catalysts comprising hydrides, coordination complexes or organic compounds; containing organic compounds or metal hydrides
C07C	Chemistry; Metallurgy; Organic Chemistry; Acyclic or carbocyclic compounds
C07H	Chemistry; Metallurgy; Organic Chemistry; Sugars; derivatives thereof; nucleosides; nucleotides; nucleic acids
C12P	Chemistry; Metallurgy; Biochemistry; beer; spirits; wine; vinegar; microbiology; enzymology; mutation or genetic engineering; fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture

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