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Supplement to the Treatise

WOLFGANG RUNGE: TECHNOLOGY ENTREPRENEURSHIP

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[Runge:page number(s), chapters (A.1.1) or other chunks, such as tables or figures].

The current case deals with entrepreneurship referring to a technology push situation in the context of a competitive group of firms. It includes also the German firm IoLiTec GmbH and Bioniqs Ltd./Scionix Ltd. from the UK for which also case documents were created [Runge:B.2].

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Table of Contents

Referring to ionic liquids provides exemplary insights into aspects of the *birth of markets out of science* and the approaches of entrepreneurs to grasp corresponding opportunities based on technology. Related cases tackle entrepreneurship perceived as *innovation* based on a *platform technology* with broad applicability for many markets. Furthermore, the area has a *very limited number of players.*

Solvent Innovation GmbH (SI) was founded in 1999 by Claus Hilgers and then Prof. Peter Wasserscheid as a spin-out of the Technical University (RWTH) Aachen in Germany. The firm developed, manufactured and distributed ionic liquids [Runge:2006:538-540], especially for applications as functional materials.

By January 2008 the German firm Merck KGaA took over SI with ten employees at that time and kept all the employees. It was integrated into Merck's Performance & Life Science Chemicals unit, but continued to operate as "Merck Solvent Innovation GmbH" [Dow Jones 2008].

According to Merck's corresponding press release the takeover meant *acquisition of technical know-how and experience*, as Merck at that time did research on ionic liquids only for five years, whereas the NTBF incorporated knowledge and experience gained over ten years. Furthermore, Merck obtained additional production capacities and products to access new markets with the high-performance lubricants and antistatic agents for plastics (INNOLUBE™ and INNOSTAT™).

In this regard Solvent Innovation shares the fate of another spin-out of the Technical University (RWTH) Aachen, Puron AG, which was also acquired by a large firm after a couple of years [Runge 2006:95-96; Runge:Table I.41, Figure I.73].

The Technology and Markets

Ionic liquids (IL) for broad chemical and biotechnological industrial and research applications emerged only by the end of the 1990s though they were known for decades [Runge 2006:538-540]. They are salts (with negatively charged anions and positive cations), but they are not solid as commonly salts are but liquid at low temperatures. By definition, ionic liquids are salts that have a melting point below 100 °C and are relatively low viscous. However, only a melting point below 80°C allows a broad substitution of conventional organic solvents by ionic liquids.

The major difference between ionic liquids and conventional salts – such as table salt, NaCl – lies in the asymmetry of the cation-anion pair and the delocalized charges, which lower the melting point of the salts due to a "softening" of the crystal lattice. Cations of ionic liquids are mostly derived from organic chemicals or contain voluminous organic components. A result: N-methylimidazolium chloride – with a voluminous organic cation – melts at only 75 °C, whereas NaCl melts at about 800 °C. "Ionic liquids present a set of properties within a liquid that you did not have before." [Ritter 2008]

Replacing an organic solvent by ionic liquids leads often to remarkable improvements regarding reactivity and selectivity. In many cases the *proper choice* of the cation/anion-combination allows an optimization of the *ionic liquid solvent*, especially for a reaction under investigation. For this reason, ionic liquids are also specified as "*designer solvents.*"

Ionic liquids have been used to dissolve not only simple organic compounds, but also enzymes, polymers, even coal and nuclear waste. But replacing an existing technology and industrial process that has to be fine tuned by ionic liquids is difficult!

The choice of cation or anion can also affect other salt properties, including density, viscosity, and water stability and miscibility. Hence, t*ailor-made ionic liquids* were becoming increasingly important.

Ionic liquids form *two-phase reaction systems* with many organic product mixtures. In this way, *simple product separation* by phase separation and *easy catalyst recycling* is possible. Moreover, the lack of vapor pressure allows destillative separation of the product from the ionic catalyst solution without formation of azeotrops. In some cases the catalyst is even stabilized by the ionic liquid during distillation.

A growing variety of ionic liquids were becoming commercially available, a development that has fed the surge of (academic) research using these unorthodox liquids [Runge 2006:538-540].

By theory about 10^{18} different ionic liquids are conceivable. By 2006 the number of ca. 500-1,000 *products for R&D* and 10-20 different *commercially available industrial scale products* [Schubert 2008] seemed to be just a start for the new technical field. This ratio also demonstrates that *design of ionic liquids is a game with gigantic numbers and a field for combinatorics*.

Ionic liquid technologies usually address "*economic markets*" [Runge:Table I.15]. The initial fascination with the solvent – thermal, mechanical, and electrochemical properties of ionic liquids – led to a lot of *hype* [Short 2006; Ritter 2008].

Though being rather fragmented into *many relatively small markets* this totally new technical area attracted not only some notable startups and NTBFs (Solvent Innovation GmbH and IoLitec GmbH in Germany, Scionix Ltd. and Bioniqs in the UK), but also large chemical companies, such as German Merck KGaA (which acquired Solvent Innovation GmbH) and Evonik Industries (previously named Degussa), Cytec and Covalent Associates in the US as well as the chemical giant BASF in Germany.

> Concerning entrepreneurship it is notable that IoLiTec has been founded by a former employee of Solvent Innovation.

As is shown by IoLiTec founder T. Schubert [2008] ionic liquids were perceived as a *platform technology* [Runge:Table I.12, Table I.51] with a very large number of envisioned commercial applications. He listed 26 specific applications clustered into 6 different general areas. A corresponding slide of a presentation (available with the author) was published by IoLiTec already in 2004 [Schubert 2004], one year after its foundation.

Having such a *broad choice set of opportunities* requires careful selection and setting priorities. And the setting of priorities usually means making hard choices among conflicting (sub)goals.

But publicizing and illustrating the broad spectrum of applications for ionic liquids was not only meant to show what choices IoLiTec could make from existing options and which ones it finally made. The spectrum of applications was additionally made public to prevent any entrant to patent a particular application and thus constrain IoLiTec's further expansions into other applications of interest to them.

A fundamental *obstacle* for commercialization of ionic liquids is *high cost* which may be €500 - €2,000 per kg [Editorial Staff 2007]. High costs, however, seemed surmountable. "The price might look bad in the beginning, but it is always price-to-performance that is important." If the performance of an ionic liquid is 20 times that of the material it aims to replace, for example, a customer would need much less of the ionic liquid [Short 2006].

A further obstacle is the *analytics* of ionic liquids. Literature data revealed that results were not reproducible. An analytical standard process was lacking. The critical factors associated with the preparation process refer essentially to content of water, or of chloride or bromide ions. Already additional ten percent of chloride changes the melting point by twenty degrees. This is killing pharmaceutical syntheses, for which already small deviations from the specification may crash a process [Editorial Staff 2007].

Still in 2006 Evonik (Degussa) *dampened expectations arising from early research into ionic liquids*, particularly with regard to widespread applicability. It was pointed out: "Most of the ionic liquids that academia is playing with are new chemicals. They are not listed." "They can be used in research but can't be used in large quantities without being registered with the authorities around the world." [Short 2006] And this means considerable amounts of time and money.

And in 2007 it was still questioned whether ionic liquids could become a new platform technology over the next years. SI's co-founder Hilgers showed patience. "In two to three years we shall know whether the breakthrough is achieved." ("In zwei bis drei Jahren wissen wir, ob der Durchbruch geschafft ist.") [Editorial Staff 2007]

From Evonik (Degussa) on learns: "Researchers have some degree of freedom to work on potential projects and to be innovative. But once something becomes a bigger, controlled project, questions come up: Toxicity? Raw materials? Availability? Listing? These questions do kill some projects." [Short 2006] The toxicology and eco-toxicology of an ionic liquid will mainly depend on the cations. And the problem for commercialization was the following.

> Companies will not develop a compound, manufacture it, and go to the expense of registering it, just in the hope that an application can be found. On the other hand, customers are reluctant to develop applications for compounds that have not yet been registered

By judiciously choosing the cations, in particular, effort to get some of the analogs with "safe" cations listed will be less.

Moreover, the use of ionic liquids replacing organic solvents will always raise a couple of additional questions concerning its role as a reaction medium: Will the different stability in ionic liquids lead to alternative reaction pathways? Will the expected changes in reaction kinetics shift the balance between thermodynamic and kinetic control?

Solvent Innovation's founder Hilgers was aware of such issues saying "For any application, we try to talk with companies about materials already registered. But if those aren't appropriate for the customer's problem we develop other materials. We tell the customer it will be about six to nine months for full registration and that cost will be included in the development costs." [Short 2006]

Dr. Hilgers' [2006] comment as an entrepreneur on the whole situation and opportunities with ionic liquids was: "I am personally convinced that the entire field of ionic liquids will be significantly pushed ahead and I look positively forward to the future" ("Ich persönlich bin davon überzeugt, dass dadurch das gesamte Feld der Ionischen Flüssigkeiten signifikant vorangetrieben wird und sehe der Zukunft positiv entgegen.") [Hilgers 2006].

For many small companies in the field a market worth $1 million per year is attractive. However, large companies in the arena, such as BASF, Evonik (Degussa), Merck, and Cytec Industries, have different scales for success. "Someone in each of those companies is saying, "There's a project in my plans that will have sales of $10 million or $20 million per year eventually." [Short 2006]

> By 2008 reality has set in; the types of global-scale processes utilizing ionic liquids that were initially envisioned have not appeared. Instead, a steady stream of small, niche applications has formed. Furthermore, the Great Recession 2009/2010 also left their traces in the field.

The focus of the chemical industry has shifted away from simply replacing organic solvents. The list of uses still includes solvent applications, but it has greatly expanded to essentially include production of nanoparticles; electrolytes in sensors, solar cells, and lithium-ion and other types of batteries; multi-phase catalysis; lubrication; performance additives for paints and coatings; chromatography columns; gas adsorption and storage; and pharmaceuticals and drug delivery systems.

A host of academic groups was busily expanding the limits of what is known about ionic liquids.

For instance, *dye-sensitized solar cells* (DSSCs) were assumed to be an emerging market for ionic liquids, such as an imidazolium-based ionic liquid made by IoLiTec GmbH (B.2). In DSSCs light passes through a transparent coated glass electrode and interacts with the sensitizer dye. Electrons gleaned from the dye are transported by the ionic liquid electrolyte to a second coated glass electrode.

The photovoltaic process used is roughly similar to photosynthesis in plants: A special ruthenium dye assumes the role of chlorophyll, turning light into electrical energy in a chemical process. Specifically adapted to the electrode and dye system, the ionic liquids are key to ensuring that the solar cell will generate power in a reliable and stable manner.

The cells typically are sealed, so the extremely low vapor pressure of ionic liquids is a key property; pressure does not build up inside. Commercial applications of DSSCs entering the market include power sources to recharge portable electronics and smart windows in buildings [Ritter 2008].

In 2007 G24 Innovations Ltd (G24i), from Cardiff (UK) and founded in 2006 by a "veterans approach", and BASF announced a joint development agreement. The program would develop ionic liquids and formulations that further improve both performance and efficiency of G24i's solar cells using a proprietary DYE SENSITIZED THIN-FILM technology. G24 was the first company in the world to produce DSSCs at an industrial scale. Its proprietary high speed roll-to-roll manufacturing process allowed for large volume production at its 23 acre, 187,000 square foot facility [G24 Innovations 2007].

G24i's technology provides a uniquely thin, extremely flexible and versatile nano-enabled photovoltaic (solar) material that converts light energy into electrical energy, even under low-light, indoor conditions. Thus, even in the absence of direct sunlight, electric energy can be generated in both a convenient and efficient manner. G24i's DSSC has been declared as the world's most powerful indoor photovoltaic module. However, G24i's business ran into some problems with ultimately changing ownership. G24 Power has re-started producing solar cells after buying G24 Innovations as GCell (http://gcell.com/) [PEW 2012; Hall 2013; Watterson 2013].

Also Merck KGaA was active in the field supporting commercial development of DSSCs. Dyesol Ltd. and Merck signed in 2009 an agreement to collaborate in the development of electrolytes for use in DSSC. This joint development agreement would be the precursor to potential future commercial arrangements with Merck to manufacture existing and next generation electrolytes for application in DSSC [Handy 2009].

Merck launched livion™ as a brand for dedicated DSSC-dedicated electrolytes with common solvents, ionic liquids or a combination of both in addition to other components. The DSSC electrolytes incorporate Merck's Solarpur® materials single materials or Merck chemicals treated in accordance with Solarpur® standards. The DSSC modules were produced by Fraunhofer ISE resulting from a German Ministry of Education and Research (BMBF) project "Scalable dye-sensitized solar cells – Development of new electrolytes for dye-sensitized solar cells with long-term stability." In 2011 Merck presented the first large-size glass-based screen-printed DSSC solar panel prototype from Fraunhofer ISE containing Solarpur® materials [Diergardt 2011].

By 2010 the potentials and prospects for ionic liquids use were still vast and the growth too. 990 new patents demonstrated the growing interest in ionic liquids. The Ionic Liquids Markets World-wide is forecasted to reach $3.4 billion by 2020 from 300 Million today. Catalysis and synthesis is seen as the biggest application by value. German companies and US companies lead the market and developments with a share today of 70 percent [Helmut Kaiser Consultancy 2010].

The Entrepreneur(s)

Before his study Claus Hilgers (born 1970) served in the German Army (1999-1990). He studied chemistry at the University of Cologne (Germany), but did his diploma thesis (1997) at the University of California in Berkeley and doctoral thesis 1998-2001 at the Technical University (Rheinisch-Westfälische Technische Hochschule – RWTH) Aachen in Germany [PFAU].

Claus Hilgers, the entrepreneurial founder of Solvent Innovation GmbH in September 1999, appreciates the high degree of *self-determination,* being his own boss [Hilgers 2006]. He had played with thinking about running his own business, because for him *independence* is a special kind of *self-realization*. His *motivation* was to *develop own ideas and implement these* creatively according to his way. Additionally, Hilgers is *open-minded* for learning, as he was attracted to deal not only with special technical issues, but also to deal with all aspects of corporate leadership [PFAU].

After having sold his firm to German Merck KGaA in 2007 Claus Hilgers founded the investment firm LIQION CAPITAL GmbH as a managing director and partner in 2008.

Dr. Peter Wasserscheid became a founding partner of the firm rather than being an dedicated entrepreneur. He is in the best sense a "scientist" who followed an academic career track. After his PhD at the RWTH Aachen he worked as a post-doc at BP Chemicals in the UK. He is viewed as one of the pioneers of research and development in the field of ionic liquids. The systems he developed are already used in industrial processes. In October 2003 he became full professor at the University of Erlangen-Nürnberg (Germany) where he heads the Chair of Chemical Reaction Engineering [DFG 2004]. He (co-)authored 55 publications and 21 patents.

He then served as a member of the Advisory Board of Solvent Innovation and related very closely to management as a "Scientific Supervisor." Wasserscheid was a member of the executive board of Solvent Innovation between 1999 and 2003 and acted as a Scientific Supervisor since 2001.

Awards and Publicity

Solvent Innovation or their founders, respectively, gained some publicity that was assumed to be helpful by Hilgers [2006].

In 2002 for its AIMFEE™-(Advanced Ionic Materials for Enhanced Efficiency) technology to use ionic liquids for innovative liquid materials in chemistry and life science SI received the "Innovation Award of the German Economy" (Innovationspreis der Deutschen Wirtschaft) for startups. This award is provided by the German business magazine "Wirtschaftswoche" and the Business Club Rhine-Main (Wirtschaftsclub Rhein-Main) and sponsored by the public KfW bank (cf. below tbg).

In 2006 Venture Lounge, which brings together new firm founders, established firms' owners and venture capitalists, via participating firms' owners and VC- reviewers chose Solvent Innovation

GmbH to be the winner of the pitch for the segment “Hightech & Cleantech” for its excellent presentation of its business idea and subsequent standing in “questions & answers” sessions as well as one-on-one discussions. It won the VentureLounge-Award “Cleantech 2006” [Venture Lounge 2006; UpTech Network 2006].

And according to Dr. Michael Brandkamp, member of the jury and managing director of the German “Hightech-Gründerfonds Management GmbH” (HTGF, financing young technology companies) the summary of the jury’s assessment was ”SI has the best prerequisites to become an international key player in the field of so-called Ionic Liquids in the next few years” (“SI hat die besten Voraussetzungen, in den nächsten Jahren zu einem internationalen Keyplayer im Bereich sogenannter Ionic Liquids zu werden”) [UpTech Network 2006].

In the same year Prof. Peter Wasserscheid received the German Gottfried Wilhelm Leibniz-Prize 2006. Through this award scientists working experimentally using highly complex apparatuses are honored. The prize is worth €1.55 million and Prof Wasserscheid shared it with Prof. Dr. Matthias Beller of the University of Rostock.

The Business Idea, Opportunity and Foundation Process

With regard to commercialization of ionic liquids in 1980 there were only a few patent applications for ionic liquids. In 2000, there were nearly 100 patent applications, and by 2004, more than 800. This was seen as a move from pure academia to commercial topics [Short 2006]. By 2008 more than 1,500 ionic liquids have been described in the chemical literature, and some 500 ionic liquids were produced commercially [Ritter 2008].

Before foundation of Solvent Innovation in 1999 availability of ionic liquids in commercially relevant quantities did not exist. A small number of systems for laboratory experiments could be purchased from catalog firm Sigma-Aldrich [Wagner and Hilgers 2008]. Furthermore, Cytec, Acros and other “catalog firms” had supplied the *laboratory market* with ionic liquids for years and public R&D and pharmaceutical companies, such as GlaxoSmith-Kline and Schering-Plough or chemical firms like DuPont and Solvay. These kept close to the latest developments by funding research consortia, such as the Queen's University Ionic Liquids Laboratories (QUILL) in the UK [ICB Americas 2004].

Claus Hilgers [2006] entered the field already during his thesis with the selection of the dissertation topic. Through reference by a friend, after studying chemistry in Cologne (Germany) and having performed a diploma thesis in the US, he went in 1998 to Wilhelm Keim, Professor of Technical and Macromolecular Chemistry at the RWTH Aachen. Under the leadership of Dr. Peter Wasserscheid a working group emerged that dealt with the synthesis and applications of ionic liquids. Hilgers’ task here was to oligomerize ethylene in ionic liquids. But the used catalysts were extremely sensitive to impurities. Hence, Hilgers had to focus on preparing the related ionic liquids highly pure. Generally “purity/quality” is a serious issue for commercializing ionic liquids [Wagner and Hilgers 2008] because of a quality/purity-price trade-off. [1]

Simultaneously industry became more interested in these special kinds of solvents. And as they were not commercially available at that time, Wasserscheid’s workgroup received an increasing number of requests for samples [Hilgers 2006]. “We were bothered by companies wanting samples of ionic liquids. It was just too much,” said Claus Hilgers. Talks with industry professionals indicated that people wanted the ionic liquids and were willing to pay for them [Short 2006].

When development of demand reached a certain level, Wasserscheid und Hilgers recognized the opportunity for a business. When enough potential customers showed up both founded Solvent Innovation GmbH (LLC) in autumn 1999 to supply obvious customers with kilogram quantities. Hilgers acted as a partner and Managing Director (in German Geschäftsführender Gesellschafter) of the LLC.

> Solvent Innovation claimed to have become the first commercial supplier of ionic liquids which means accordingly, it was the "*first to market*".

Peter Wasserscheid served as a research supervisor. Claus Hilgers cared about all the operational tasks of the joint undertaking. Therefore, he worked his way into the details of a company's founding and managing.

As a scientist being confronted with becoming an entrepreneur he realized to lack any related knowledge. Hence, he asked commercially experienced relatives, visited founder workshops, and participated in business plan competitions, such as NUK New Entrepreneurship Rhineland or Science4Life. Apart from recognitions, according to Hilgers, this helped the startup; the business model could be discussed with outsiders.

Prof. Keim supported Hilgers und Wasserscheid. He accepted that Hilgers did not invest so much time in research as he could without the commitment to the company. Yet he pushed that Hilgers completed his doctoral thesis in 2001. And Hilgers admitted later that this was a good thing.

The company's founders were both pioneers in the development and application of new ionic liquids with enhanced efficiency. The most significant research results of Wasserscheid and Hilgers were combined to form a unique technology platform, the AIMFEE™ technology (Advanced Ionic Materials for Enhanced Efficiency). Rhis was seen as the basis and a powerful tool for numerous potential applications in life science and chemical synthesis as well as catalysis and material science.

The business idea emerged already at the end of 1998. But, the initial idea was subjected to careful considerations. And it took about a year until the Solvent Innovation GmbH was formed in September 1999. In the early days Solvent Solutions viewed itself more as a partner for systems solutions in the field of ionic liquids rather than only a producer.

It also offered custom synthesis of specialties and contract research. Early customers included the big names in the chemical and petrochemical industry. Sales in the first year of existence (2000) was ca. DM100,000 (€50,000) with three employees and an expectation of ca. DM280,000 (€140,000) for 2001 with five employees, respectively [PFAU].

Solvent Innovation did not need external financing during its *startup thrust phase* [Runge:ch. 4.3.2; Figure I.125], its first three to four years of existence [Hilgers 2006]. On the one hand, the founders could utilize the laboratories and the infrastructure of the university. Furthermore, after Hilgers' scholarship for his thesis ended the program PFAU ("Programm zur Finanziellen Absicherung von Unternehmensgründern aus Hochschulen") of the State Government of North-rhine-Westphalia secured his cost of living.

The PFAU program financed founders of the state universities for a maximum of two years by a quasi-salary. Hence, Hilgers did not need to make revenue, but could concentrate on developing the business. Hilgers was supported by PFAU for the period July 1, 2000 until June 30, 2002 [PFAU].

The time of the PFAU scholarship was used essentially for generating a technical Proof-of Concept (PoC), developing concepts for financing and distribution and market tests. During that period also two new processes were developed with the claimed to *reduce production cost by 35 percent and increasing quality* and they submitted these also as patent applications [NRW 2003].

According to Hilgers [2006] in 2003 Solvent Innovation reached a state of development which required a step for growth to position itself more securely in the field (… "an dem wir einen Wachstumsschritt machen mussten, um uns auf dem Gebiet sicherer positionieren zu können."). By and by investing they succeeded and after 2002 Solvent Innovation hired new employees and by 2006 there were ten employees (Table 3), four of them being chemists with a doctoral degree [Hilgers 2006].

Market Entry, Expansion and Diversification

Solvent innovation could not finance distinct growth, which required also a new location, by sufficient own revenues (cash flow) and, hence, looked for an investor. As there where already contacts with the German large specialty chemicals firm Evonik Industries (named Degussa at that time) Hilgers succeeded in getting Evonik on board as a third (minority) partner for the GmbH (LLC). Evonik as a strategic investor was seen as an advantage, as this one understands the technology faster than an institutional investor – as one just does not have to explain so much to a corporate investor [Hilgers 2006]. Actually, Creavis Innovation & Technology, the 100 percent subsidiary of Evonik devoted to innovation and new business development [Runge 2006:557, 698, 698], was involved.

A remark concerning “Investor Relations” on the Solvent Innovation Web site at that time revealed that “on July 24, 2003 Solvent Innovation sold a minority share to Degussa and completed its growth financing deal together with the public investment organization tbg Technologie Beteiligungsgesellschaft mbH der Deutschen Ausgleichsbank.” Currently, tbg of Bonn (Technologie Beteiligungsgesellschaft des Bundes) is an investment organization of the German Federal Government and part of the public KfW Group.

In a US SEC document related to the German power and utilities giant firm E.ON AG [SEC 2004] one finds the entry “<10 %” for Solvent Innovation related to the heading “Stake related to E.ON”. E.ON was the owner of Degussa until 2004.

According to Evonik ”The purpose of the strategic partnership that we have entered with Solvent Innovation is to obtain ionic liquids as a new product category for large-scale production applications.” Evonik aimed to produce and market *ionic liquids as specialty chemicals, particularly for technical applications*, such as pigment-sensitized solar cells, high-capacity batteries, fuel cell membranes, plastics additives and special functional coatings [ICB Americas 2004].

According to the “Eletronischer Bundesanzeiger” (Electronic Federal Announcements) by the end of 2006 the key items of the financing structure are given in Table 1.

Table 1: Key financial components of SI’s financial structure by the end of 2006.

Financial Component	**Details**
Share capital (Stammkapital) of the LLC (GmbH)	€32.250,00 Prof. Dr. Wasserscheid, Dr. Hilgers, Creavis GmbH
Loan by Dr. Hilgers	Unknown amount; since Sep. 27,.2002 at 7 % interest
Loan Creavis GmbH for ten years	€500,000 The Creavis loan of 2003 is at EURIBOR [1)] plus 1% annual interest
“Loan” of tbg, is a “silent participation” (ends Dec. 31, 2013)	€5750,000 This amount will be every six months at 8% interest. The interest is a minimum compensation; according to the participation agreement it can be increased when achieving surpluses to a maximum of 12%.

1) EURIBOR (Euro Interbank Offered Rate) is a daily reference rate, published by the European Banking Federation, based on the averaged interest rates at which Eurozone banks offer to lend unsecured funds to other banks in the euro wholesale money (Wikipedia).

The new financing structure kept Solvent Innovation independent and retained ownership and control with its two founders. Solvent Innovation was not obliged to report to Evonik about the operative business, and also a know-how transfer did not occur. Moreover, Solvent Innovation with a claimed production capacity of 20 metric tons per year (by 2006) had the option to let Evonik produce more for the NTBF if needed [Hilgers 2006].

Growth meant that Solvent Innovation could no longer stay in the university – corresponding offices and production facilities were not available. The requirement of appropriate buildings and facilities for installing the plants led to select the Biocampus Cologne as a location, a sort of technology park for small chemical and biotechnological ventures.

In February 2004 Solvent Innovation moved to its new site at the Biocampus Cologne. Since then Solvent Innovation manufactured its products in Cologne and had an option on the neighboring building so that the site could be extended without problems.

Laboratories and production rooms or buildings could be rent and tenants were offered office and other services. In particular, the park conceded partially rebuilding an empty building to obtain a hall with the necessary height to cover the production units [Hilgers 2006]. Here, the company operated in 600 m² of lab and office space.

Business orientation was driven essentially by the fact that published research results indicated that the unique character of ionic liquids could open up new "solutions" for catalysis and organic synthesis emphasizing the "green" character of ionic liquids for chemical processes in terms of

- Replacing volatile organic solvents,
- Minimizing the consumption of catalyst,
- Enhancing the overall activity and selectivity of chemical processes.

In order to meet apparently *rising market demands for ionic liquids in larger quantities*, in 2005 Solvent Innovation increased its capacities distinctly with the acquisition of a new 100 l plant. Together with the already existing 25 l plant and two 20 l reactors at that time Solvent Innovation itself had an annual production capacity of more than 5 metric tons. With these facilities the lead time for 100 kg quantities was significantly reduced to three to four weeks depending on the production schedule [Solvent Innovation 2005].

By 2006 the relatively small group of players in the field of ionic liquids was split between a group of very large companies and NTBFs. At that time Solvent Innovation had a claimed capacity to produce 20 metric tons of ionic liquids per year. According to Hilgers, "We could extend up to 50 or 100 metric tons, but that's it. We won't go beyond that. We are positioned between the global players and the small guys." If his company would need significantly larger quantities, he added, it would work with Degussa (Evonik), BASF, or another large company to actually produce the compounds [Short 2006].

Between 2005 and 2007 Solvent Innovation showed a *business re-orientation*. The industry's concept of what ionic liquids can do had evolved significantly. Therefore, Hilgers changed the business model. Over time it had turned out that positioning and commercialization of ionic liquids as a replacement of organic solvents for syntheses were not sufficient for distinct growth. Solvent Innovation should no longer be viewed as only a producer of solvents.

According to Hilgers, "There are a lot of applications, starting as a replacement for solvents. But we are now in *advanced materials and functional compounds*. That is the direction where we see the future, rather than classical chemistry." Other market possibilities, he said, include high-performance lubricants, compressor fluids, and dispersion of nanoparticles in various kinds of matrices." [Short 2006] Also applications as electrolytes in electrochemistry (high-performance batteries) were envisioned. These applications became the focus of activities of Solvent Innovation – and also those of its close German competitor IoLiTec (B.2).

This shift of emphasis away from the solvent aspects was associated with a *different type of customers*. And the firm had to learn that for the market of functional materials the times from first contact to applications with the customer are significantly shorter. Until a customer replaces the solvent in a running process an extremely long time will pass. Other applications of ionic liquids can be implemented within one or two years [Hilgers 2006].

Solvent Innovation strove for becoming *a systems and solutions provider*. "The unique properties of ionic liquids are solving problems. At least that's what we're doing," "The industry has become a little more grown-up. Solvent Innovation has grown up as well. "We are a systems solution provider in ionic liquids," Hilgers said "We started with supplying, and now we offer the complete portfolio of *customer services: joint development, consultancy*, and so on. We support our customers and help them to be more successful. Just supplying new technology is not sufficient." [Short 2006]

As a marketing tool, for new customers Solvent Innovation offered dedicated kits for special applications, such as synthesis and catalysis, biotechnology, engineering and electrochemistry. According to Hilgers, "Our Ionic Liquid Kits will allow our customers a particularly easy access to the technology through promising systems." [Editorial Staff 2007]

Organization, Business Model and State of the Firm Just Before Being Taken Over

By 2006 (with ten employees) Solvent Innovation had an Executive Management (Table 2) whose members filled the organizational roles which are necessary for growing a small firm. This team was also present in 2007 [Wagner 2006a; 2007].

Table 2: Executive Management of Solvent Innovation GmbH by 2006.

Dr. Claus Hilgers	Dr. Marc Uerdingen	Dr. Markus Wagner
President & CEO (Founder)	Head of Research & Development	Head of Marketing & Sales
Studied chemistry; responsible for strategic planning, human resources, finances and sales	Studied chemistry; before his move to Solvent Innovation he was for one year in charge of the Quality Assurance Department of Maxim's Brand products (cosmetics industry)	Studied chemistry; after working for the Bayer AG in R&D he joined Solvent Innovation in 2003

Apart from Prof. Wasserscheid and Prof. Keim of the RWTH Aachen (Germany) and his successor Prof. Dr. Walter Leitner, the *Advisory Board* of Solvent Innovation contained a large number of German academic experts in the fields of bio-processing technologies (Prof. Dr. Udo Kragl) as well as professors from industry (Prof. Dr. Herbert Hugl (ex Bayer Ag), Prof. Dr. Klaus Kühlein (Hoechst AG). Furthermore, Solvent Innovations had a network of contacts with many academic experts in various fields relevant for ionic liquids.

By 2006/2007 the situation of Solvent Innovation as a supplier of offerings on the basis of ionic liquids can be described as follows [Wagner 2006a, 2007].

- 10 employees
- Technology protected by 11 patent families (product or application patents)
- 60 products for the market (70 for 2007)
- 200 international customers
- Production capacity of 20 metric tons per year.

Concerning the issue of scaling-up IL startups considered to limit themselves concerning production capacities. For instance, Claus Hilgers said [Short 2006], as mentioned above: "We could extend up to 50 or 100 metric tons, but that's it."

And there was a new business model. Products would be sold directly via a *catalog business* or via *distributors*. SI focused on the fields of

- Separation
- Analytics
- Organic Synthesis
- Enzymatic Biocatalysis
- Electrochemistry

- New Materials.

Solvent Innovation offered two kinds of products [Wagner 2006a, 2007]:

- Platform products – pure ionic liquids
- Integrated products – finished formulated products and masterbatches.

Examples of platform products comprised, for instance,

- Doping of semiconductors with corrosive gases: IL acts as a gas storage medium;
- Production of fine chemicals: IL acts as a scrubbing medium.

A masterbatch is a product in which components (often pigments and/or other additives) are already optimally dispersed in a carrier material that is compatible with the main target/material in which it will be used. Integrated product classes were, for instance,

INNOLUBE™ High-performance lubricants and electrically conductive lubricants	INNOLUBE™ acts as an electrically conductive lubricant for a bearing in frequency-controlled motors
INNOVAC™ Liquid for vacuum pumps and compressor fluid for screw compressors	INNODISPERS™ Dispersing agents for nanoparticles
INNOSTAT™ Anti-static agents for plastics and coatings	AMMOENG™ acts a dispersing agent, for instance, for homogenization of color pigments

SI estimated the market potential for INNOLUBE™ products to have a value of €300 million, that for INNOSTAT™ products being €500 million [Wagner 2006b].

Based on the new business model Solvent Innovation expected to achieve revenues of ca. €1 million in 2006 [UpTake Network 2006]. However, it appears that most of the products had still a status of *prototypes* – as can be inferred from a presentation of Wagner [2007]. He lists various INNOLUBE™ and INNOSTAT™ products explicitly as being prototypes.

Prototype INNOSTAT™ anti-static agents, such as INNOSTAT™PU; INNOSTAT™PVC, and INNOSTAT™PC target the polymers and plastics commodity markets of polyurethanes, polyvinylchlorides and polycarbonates which are produced since decades on a million tons level relying on an established set of highly competitive suppliers of processing aids and additives.

To replace existing anti-static agents for well established and optimized manufacturing processes would mean that "technical specification of customers met", as noted by Wagner [2007] for INNOSTAT™PU, does not suffice. SI had to fight against switching costs and convenience and customers taking the risks these additives to function not only in a laboratory or pilot plant 500 kg level, but in a multi-million tons plant.

In 2006, to push growth Hilgers looked to catch €2 million of investment capital [Wagner 2006b] to achieve the goals of increasing revenues fivefold by 2009 ("Bis 2009 wollen wir unseren Umsatz verfünffachen") [UpTake Network 2006] and expanding production capacity to 100 tons per year [Wagner 2007].

SI targeted an institutional investor to finance finishing its "products" and the development of the market by sales professionals. SI stressed its strong IP-position and technology protection by eleven patent families and differentiation from the competition by focusing on other target markets. The biggest risk was associated with the *challenge of efficient market penetration* for the newly developed products INNOLUBE™ and INNOSTAT™ [Wagner 2006b].

But, by the end of 2007 German Merck KGaA completed its acquisition of SI for a purchase price of €2 million [Merck KGaA 2008]. The takeover meant for Merck *acquisition of technical know-how and experience*. Furthermore, Merck obtained *additional production capacities and products* to *access to new markets* with the high-performance lubricants and antistatic agents for plastics.

Key Metrics

To describe SI's development in Table 3 the number of employees of Solvent Innovation are given. The plateauing of employees' numbers Indicates having reached a state at a cross-roads.

Table 3: Numbers of Solvent Innovation's employees and revenue by year.

1999	2000	2001	2003	2006	2007
Number of Employees					
2	3		5	10	10
[PFAU]	[PFAU]		[Solvent Innovation 2003]	[Wagner 2006a]	[Wagner 2007]
Revenues	€50,000	ca. €140,000		Just €1 mil.	
	[PFAU]	[PFAU]		[UpTech Network 2006] *)	

*) Defined as a goal.

Competition

One of the leaders in "greening" of chemistry was Queen's University's Prof. Seddon, an important academic player in ionic liquids since the early 1980s. In 1999 he enlisted the support of DuPont, Exxon, ICI, Merck KGaA, Schering-Plough, Smith-Kline Beecham, Solvay and other companies in a consortium known as QUILL (Queen's University Ionic Liquids Laboratories) [ICB Americas 2004].

NTBFs focusing on ionic liquids and founded around 2000 encountered often competition by large chemical firms with which the NTBFs originally had sales or production agreements.

After 2005 large or giant global firms like Evonik (Degussa), Merck KgaA or BASF looked for large-scale applications of ionic liquids and had increased their in-house production capacities to the multi-ton level for selected applications. Furthermore, these companies had reduced lead time for standard ionic liquids to a few weeks [Wagner and Hilgers 2008]. BASF and Evonik (Degussa) focused on coatings, paints and inks.

BASF entered the field in 2002 with a process it called BASIL (Biphasic Acid Scavenging Utilizing Ionic Liquids). The process became alive in October 2004 as part of a new route to precursors for photoinitiators that are used as additives in UV-curable coatings [Short 2006]. Furthermore, BASF was committed to using ionic liquids to process cellulosic materials. Cellulosics form stable solutions in ionic liquids and cellulose can then be regenerated through precipitation by the addition of water, methanol or propyl alcohol to make cellulose-polymer blends as unique types of plastics.

BASF and the University of Alabama formalized a license and cooperative agreement giving BASF exclusive rights to patents covering the use of ionic liquids to dissolve, regenerate, and process cellulose. "This technology enables us to produce blends of polymers and cellulose that provide excellent plastics performance." [Short 2006]

BASF has used the BASIL process also to manufacture alkoxyphenylphosphines batch-wise. However, that process has general applicability. According to BASF, "Whenever acids are formed or used (for instance, as a catalyst) in a chemical reaction and the reaction mixture would suffer from an aqueous work up, BASIL can be used advantageously to scavenge acids or remove them," pointing to a manifold of chemical processes, such as esterifications, acylations, silylations, phosphorylations, sulfurylations, eliminations, deprotonations and acid removals as candidates.

BASF believed that BASIL is *the first commercialized process to use ionic liquids*. [ICB Americas 2004]

Additionally, BASF demonstrated the possibility to increase the yields of reactions by recycling the new solvents and, in this way, establish cycles of material [Editorial Staff 2007]. The process permits use of a smaller reactor, significantly increases the yield, speeds up the reaction, and allows the imidazole (used as the cation) to be recycled.

BASF then used the process for additional reactions and was licensing the technology. When it comes to commercial processes, BASF has the largest ionic liquid patent portfolio and access to the broadest range of potential applications [Ritter 2008].

A number of other companies, including Eli Lilly & Co., Air Products & Chemicals, Linde, Wacker Chemie and Scionix, have pilot-scale ionic liquid technologies under development. But many companies provide technological *know-how related to ionic liquids to develop larger markets for their products* – they do not just make and sell ionic liquids.

Evonik's (Degussa's) focus of market development turned to exploiting the functional properties of ionic liquids. The company had already synthesized ionic liquids and after 2003 marketed R&D quantities through Solvent Innovation. But it also had already developed some specific applications. "We are selling ionic liquids to our customers as performance additives such as dispersing agents in paints and inks." [Short 2006] Evonik, for example, is using ionic liquids as solvents in an in-house process to functionalize polysiloxanes [Ritter 2008].

Evonik cited interest in developing ionic liquids as *potential replacements for mineral oils and synthetic lubricants*. On the other hand, Evonik raised a caveat: "every time you think of an application, there will be drawbacks as well." For example, a lubricant formulator seeking to substitute an ionic liquid for a mineral oil might encounter compatibility problems with sealants that have been developed to work with mineral oil [Short 2006].

BASF, Evonik, and Merck KGaA, which are all based in Germany, along with US-based Cytec Industries, are part of a small group of global players in the ionic liquids arena that are looking at a variety of commercial opportunities.

Differentiation in the ionic liquid markets is sometimes related to the types of cations used. For instance, the startup Bioniqs Ltd. (B.2) focused on special ammonium salts (nitrogen-based cations), whereas Cytec emphasizes phosphonium ionic liquids (phosphorus-based cations).

Bioniqs did not compete directly with Solvent Innovation as it provided designs and developed proprietary ionic liquids which facilitate and improve bio-chemical and bio-catalytic processes.

Merck began working with ionic liquids for battery applications in the mid 1980s, though the project was ultimately dropped. In 1999, the company was one of the co-founders of QUILL, in which it took a fairly passive role, following developments and considering how it might use ionic liquids. In 2002, however, Merck restarted its own ionic liquids program. "We decided we would try to sell compounds and see if there was interest." [ICB Americas 2004]

Similar to US Sigma-Aldrich Merck KGaA operates not only as catalog company, but is a large pharmaceutical and specialty chemicals firm. Its current Merck's Chemicals & Reagents Catalogue lists thousands of items on more than 1,800 pages (for biosciences, cosmetics, food, liquid crystal displays & emerging technologies, pharma and printing, plastics, coatings) that can be accessed by sophisticated search options via the Web or smartphones. Merck has the know-how to produce low melting salts with high quality. Visitors to Merck's Web site can search the catalog based on the properties the customers desire and identify, for example, the ten compounds most closely matching their criteria. These could then be tested in their labs.

At the same time, if a customer wants a compound that suits its requirement more closely, Merck has the know-how to design and manufacture it. "The potential for different properties is tremendous," "Finding the best solution requires a lot of research. Merck is associated with 15 different research institutions worldwide with expertise, so they have a lot of knowledge to offer the customer." [ICB Americas 2004]

By 2004 Merck already had more than 250 compounds accessible on its Web site, many of them based on building blocks patented by the company. Merck explained, “We've put a lot of effort into analytics.” “We're doing the business a different way from other companies – not just putting together a catalog of compounds, but also giving specific data like melting point, solvation, etc., to help customers begin working with new compounds.”. [ICB Americas 2004]

Merck makes most of its ionic liquids in-house at its headquarters in Darmstadt, Germany. Large volumes are not a problem; a new multi-purpose facility built for the company's world-leading liquid crystal business is also available for manufacturing ionic liquids in the hundreds of kilograms [ICB Americas 2004].

In 2006 Merck set up a partnership agreement with Bioniqs Ltd (B.2) from the UK. Through its catalogue Merck manufactured and distributed a selected range of Bioniqs’ proprietary ammonium based ionic liquids to complement the established range of Merck Ionic Liquids perfectly.

SI encountered competition essentially by another German startup in ionic liquids, IoLiTec GmbH (B.2)

By 2006-2010 SI encountered also competition by the German startup IoLiTec GmbH (B.2) founded by a former employee of SI. Comparing selected development indicators for SI and IoLiTec for 2007 and after seven to eight years of existence in Table 4 show that IoLiTec had passed Si in terms of products per employee and customers per employee.

Table 4: Comparing selected development indicators for SI and IoLiTec.

	Employees	**Products**	**Customers**
SI GmbH	10 (2007)	70 (2007)	200
IoLiTec GmbH	10 (2007)	Ca. 150 (2007)	>400
IoLiTec GmbH	15 (2010)	>250 (2010)	Ca. 1,200

In and after 2007 Merck investigated in the liquid crystalline properties of ionic liquids, in particular, applications as electrolytes for batteries and components for process optimization. Generally, Merck intended to position ionic liquids in the “*low volume, high value*” segment of specialties in electrochemistry, separation technologies and analytics requiring a very high purity [Editorial Staff 2007].

By 2007, the year it purchased SI, Merck re-focused its ionic liquids activities and, rather than emphasizing only production and sales, they wanted to provide problem solutions to customers on the basis of ionic liquids. [Editorial Staff 2007]

References and Notes

DFG (2004): *Prof. Dr. Peter Wasserscheid* – Chemische Verfahrenstechnik / Chemical Reaction Engineering Universität Erlangen-Nürnberg. DFG Deutsche Forschungsgemeinschaft Annual Report 2003. http://www.dfg.de/jahresbericht/preise_2_gwl_beller_wasserscheid.htm (last access 5/27/2006).

Diergardt, N. (2011): *Working with Sunshine: Merck at the 26th European Photovoltaic Solar Energy Conference and Exhibition in Hamburg*. Merck press release, Sep. 1, 2011. http://news.merck.de/N/0/92BE663523B7DC60C12578FE002EEC7F/$File/PV110901e.pdf (last access 12/5/2011).

Dow Jones (2008): *Merck KGaA übernimmt Forschungsfirma Solvent Innovation GmbH (Merck KGaA takes over Solvent Innovation GmbH*). Dow Jones News, Jan. 1, 2008. http://www.finanznachrichten.de/nachrichten-2008-01/artikel-9898808.asp (last access 4/2/2008).

Editorial Staff (2007): *Thermische Verfahren – Wer die Ionen sucht, wird die Lösung finden (Thermal processes – Who searches for ions will find the solution*). Process Magazine, Feb. 8, 2007. http://www.process.vogel.de/index.cfm%3Fpk%3D57130%26icmp%3Daut-artikel-artikel-45 (last access 9/12/2007).

G24 Innovations (2007): *G24 Innovations and BASF sign joint Development Agreement.* Press Release, Dec. 11, 2007. http://www.g24i.com/press,g24-innovations-and-basf-sign-joint-development-agreement,18.html. (last access 2/20/2008); http://www.g24i.com/pages,profile,8.html.

Handy, V. (2009): *Dyesol and Merck collaborate in dye solar cells*. Green Technology Investments, Oct. 14, 2009. http://greentechnologyinvestments.kontentkonsult.com/2009/10/dyesol-and-merck-collaborate-in-dye.html (last access 2/2/2013).

Hall, R. (2013): *Bright future forecast for solar cell business*. WalesOnline, Nov. 15, 2013. Bright future forecast for solar cell business http://www.walesonline.co.uk/business/business-news/bright-future-forecast-solar-cell-6308805 (last 12/17/2013).

Hilgers, C. (2006): "I*ch kann meine eigenen Ideen umsetzen" (I can implement my own ideas*). Nachrichten aus der Chemie 54 (5), 528-529 (2006).

Helmut Kaiser Consultancy (2010): *Ionic Liquid Technologies, Markets, Applications, Companies and Developments Worldwide 2008 to 2020 and 2030*. Market Research Report, http://www.hkc22.com/ionicliquids.html (last access 2/19/2012); http://www.prlog.org/10698069-ionic-liquids-markets-worldwide-will-reach-34-billion-us-by-2020-from-300-million-today.html (last access 6/6/2011).

ICB Americas (2004): *Technology Watch: Ionic Liquids Offer New Solutions*. ICIS, Jan. 19, 2004. http://www.icis.com/Articles/2004/01/16/549791/technology-watch-ionic-liquids-offer-new-solutions.html (last access 5/7/2005).

LIQION: *Team*. http://www.liqion.de/team.html (last access 2/2/2012).

Merck KGaA (2008): *Annual Report 2008 (Konzernabschluss der Merck-Gruppe)*. Appendix – Akquisitionen, p. 81. http://merck.online-report.eu/2008/gb/serviceseiten/downloads/files/anhang_merck_gb08.pdf (last access 4/5/2010).

NRW (2003): *NRW-Existenzgründerprogramm PFAU fördert Sieger (NRWThe Entrepreneurship program PFAU supports winners*). Ministry of Science and Research – Northhrhine-Wesrphalia, Jan. 20, 2003. http://www.uni-protokolle.de/nachrichten/id/11880/ (last access 2/5/2007).

PFAU: *Solvent Innovation GmbH*. In Ministry of Schools, Science and Research of the State Northrhine-Westphalia: Vom Hörsaal in den Chefsessel (From the lecture hall to executive chair). PFAU-BestPractice/pages 32-33. http://ids.hof.uni-halle.de/documents/t1011.pdf; http://www.zenit.eu/d/finanzierung/download/broschuere_pfau.pdf (last access 2/22/2006).

PEW (2012): *G24 Innovations rescued*. Printed Electronics World, Dec. 18, 2012. http://www.printedelectronicsworld.com/articles/g24-innovations-rescued-00005022.asp?sessionid=1 (last access 1/24/2013).

Schubert, T. (2008): *Unternehmensgründung in der Chemiebranche – Ein Erfahrungsbericht (Firm Foundation in the Chemical Industry – A Report of Experiences*). Presentation Technology Entrepreneurship, Jan. 23, 2008. http://ce.ioc.kit.edu/downloads/Praesentation_Schubert.pdf (particularly slide 31).

Schubert, T. (2004): *IoLiTec*. File 4-IoLiTec.ppt as pdf-from 7/6/2004, particularly slide 5 (last access on the Web 4/30/2010).

SEC (2004): *E.ON AG*. SEC Info, Form U5S for 12/31/2004 EX-99.3;
Filed on 6/30/2005, SEC File 30-00362, Accession Number 898080-5-310, 71st "Page" of 72. http://www.secinfo.com/drD1f.z9p.b.htm (last access 4/23/2006).

Short, P. L. (2006): *Out of the Ivory Tower*. Chemical & Engineering News 84 (17), 15-21. http://pubs.acs.org/cen/coverstory/84/8417ionicliquids.html (last access 6.23.2006).

Solvent Innovation (2005): *Solvent Innovation increases production capacities up to 10 t /year*. Press Release, Oct. 10, 2005. http://www.solvent-innovation.com/pr_20051010.php (last access 12/12/2005).

Solvent Innovation (2003): *Technology Profile*. Biomeeting Point 2003 – BIOTECHNIKA Fair, Hannover Oct. 8, 2003.
http://www.zenit.de/d/europa/irc/download/biotechnica2003CATALOGUE.pdf (last access 2/22/2006).

UpTech Network (2006): *Geschäftsideen im Wettbewerb (Business ideas in competition*). News, Oct. 5, 2006. http://www.uptech-network.de/cgi-bin/index.cgi?op=nachricht&id=389 (last access 2/2/2012).

Venture Lounge (2006): "*Hightech & Cleantech*" – Sep. 27, 2006 in Hamburg. http://www.venture-lounge.de/2006/20060927.html (last access 1/30/2007).

Wagner, M. (2006a): *Ionic Liquids – Fascinating Materials for Your Challenges*. Dechema, Frankfurt, Sep. 22, 2006.
http://events.dechema.de/index.php?id=1051&suffix=pdf&nonactive=1&lang=de&site=events_media (last access 2/8/2007).

Wagner, M. (2006b): *Solvent Innovation*. Forum du financement de l'innovation et de la compétitivité, Strasbourg, Dec. 14, 2006. http://www.forum-financement.com/strasbourg/IMG/pdf/SOLVENT-TDE.pdf (last access 3/4/2007).

Wagner, M. (2007): *SI – Solvent Innovation – Fascinating Materials for Your Challenges*. Frankfurt Dechema, Frankfurt, Nov. 22, 2007. http://www.chemstart.org/Wagner_Solvent.pdf (last access 3/1/2008).

Wager, M.; Hilgers, C. (2008): *Quality Aspects and Other Questions Related to Commercial Ion Liquid Production*. In Wasserscheid, RP.; Welton, T. (Eds.) (2008): Ionic Liquids in Synthesis. Wiley - VCH, 2nd Ed., 2008. Volume 1, Pages 26-55.

Watterson, K. (2013): *G24 Innovations creditors owed more than £13m*. insider, Jul. 9, 2013. http://www.insidermedia.com/insider/wales/93902-solar-creditors-owed-more-13m (last access 10/11/2013).

Notes

1 Quality of ionic liquids

According to Wagner and Hilgers [2008], it has turned out that driving quality/purity to the highest technically possible level – as can be done in academia – is associated with high cost and hence prices, if the ionic liquid shall be commercialized. In other words in the market the desire for absolute quality of the product and the need for a reasonable price has to be reconciled. Commercial producers must try to make ILs in the highest quality that can be materialized at reasonable cost.

For some ILs suppliers may guarantee purities greater 99%, for others perhaps only 95%. By indicating the kind and amount of impurities to customers the customer can decide what level of purity he/she needs given that the customer does not have an option to purify the commercial IL him-/herself.

The consequence for the supplier is the need to carefully know about and cling to the customers' specification or cooperate with the customer to find out his/her "minimum specification" for the particular impurities. That means "customization" of the product. For the extreme of the customer to need 99.99% purity for an application with regard to a particular impurity supplier and customer have to confirm the specification and find the appropriate methods to achieve it.

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