3D IMAGE RENDERING

Market Briefing – December 2015

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INTRODUCTION

This market briefing introduces 3D image rendering. It provides an overview of the market for HPC solutions and the digital content creation and distribution, in which 3D image rendering is primarily situated. It presents an overview of primary research on the 3D Image Rendering market undertaken in conjunction with Rendicity, an Irish cloud-based rendering solutions company. It concludes with a discussion of benefits to the 3D image rendering market that CloudLightning anticipates demonstrating using simulations. The report draws on publicly available desk research from industry analysis.

INTRODUCTION TO 3D IMAGE RENDERING

Rendering is the process of converting a 3D model in to a 2D image. Rendering can be categorised as real-time rendering or batch rendering. Batch rendering is part of the critical path in a variety of sectors including animation, game design, architecture, industrial design and engineering. It is a compute-intensive process with unpredictable timelines.

End users have a number of options to render files:

1. **In-house** – most rendering is completed using in-application render engines that are integrated in to 3D animation, CAD or CAE software applications. These render engines are designed for rendering using local workstations and their tight integration with modelling software provides data associativity advantages. However, the completion time for a render is often unpredictable and long due to local workstation limitations. In addition, there is downtime associated with local rendering as the machine is often not available when rendering. End users can also use standalone render engines. These are specialised render software packages that are integrated with workflow but distinct from the modelling software thereby making the end user workstation available while rendering takes place on other machines. These may be totally standalone or plugins to the modelling software. While the end user has less downtime, these solutions incur additional software licensing, hardware and related costs. Many companies cluster computers for the sole purpose of rendering, these clusters are known as render farms. These require upfront investment in IT as well as the ongoing maintenance and support costs.

2. **Outsourced render farms** – outsourced render farms are third parties who provide rendering services using their render farms. Typically, the end user will send or upload the 3D model to be rendered to the outsourced provider who will then return the output file to the end user. The advantages of outsourced render farms are that the end user machine is available and that they can leverage all the advantages of the third party infrastructure to meet their deadlines. However, a drawback of outsourced render farms is lack of control over resource allocation and prioritisation and weaker control and protection of intellectual property.

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3. **Cloud rendering** – cloud rendering providers use their proprietary or public cloud services to use the power, security and scalability of public cloud services to provide an on-demand elastic rendering solution for rendering.

THE HPC MARKET AND 3D IMAGE RENDERING

As previously noted in the CloudLightning HPC Market Briefing, estimates of the total HPC market range from US$21bn – US$29.4bn with a CAGR of 3% to 9.9% (IDC, 2015; Intersect360, 2015). Table 1 provides a breakdown of the HPC market in 2015 by application category.

Table 1 Worldwide Technical Computing Systems Revenue by Industry/Application Area, 2015–2019 ($M) (IDC, 2015)

	2015	2016	2017	2018	2019	2013–14 Growth (%)	2014–19 CAGR (%)	2015 Market (%)
Biosciences	1,029	1,074	1,178	1,254	1,357	-6.1	6.2	10%
CAE	1,226	1,280	1,439	1,570	1,699	3	7.5	11%
Chemical engineering	177	187	195	201	217	-4.3	5.1	2%
DCC and distribution	665	708	738	793	858	1.6	7.1	6%
Economics/financial	366	404	446	489	529	-0.1	9.5	3%
EDA/IT/ISV	761	842	931	1,001	1,083	3.9	9.4	7%
Geosciences	791	864	973	1,046	1,132	-2.4	9.1	7%
Mechanical design	58	59	60	58	63	-3.1	1.6	1%
Defense	1,076	1,152	1,327	1,419	1,536	-7.3	10.4	10%
Government lab	2,088	2,268	2,734	3,032	3,216	-3.4	10.2	19%
University/academic	1,927	2,025	2,288	2,510	2,716	5.2	6.4	18%
Weather	466	502	530	570	617	-2	7.2	4%
Other	89	101	121	130	141	-0.3	8.1	1%
Total	10,718	11,467	12,958	14,073	15,165	-15.3	97.8	100%

Again, as noted in the CloudLightning HPC Market Briefing, cloud computing is small but is the fastest growing category in the HPC market (Intersect360 Research, 2015). IDC report that the proportion of HPC sites using the cloud has grown from 13.8% in 2011, to 23.5% in 2013, to 34.1% in 2015; this was split evenly between public and private clouds (IDC, 2015b). The drivers for HPC in the cloud including are similar to other application domains e.g. IT efficiency, business agility and cost transformation (Kim, 2009, Leimbach et al. 2014). Many HPC workloads are not ready to run on today's cloud architectures and most public cloud HPC

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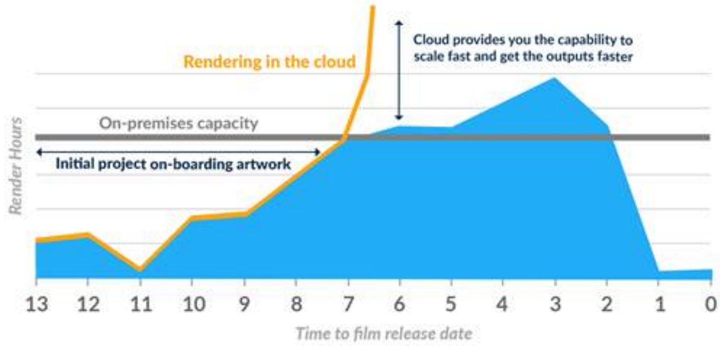
offerings are designed only to effectively support HPC workloads without meaningful communications and I/O requirements (Cloud Standards Council, 2012; IDC, 2013; IDC, 2014; IDC, 2015). IDC (2015) forecast that HPC use in the cloud will primarily relate to jobs that can be easily split across processors, surge workloads, R&D projects and trials, and smaller organisations who do not have access or cannot afford traditional HPC.

Figure 1 Cloud computing can provide animation studios with rapid scalability and throughput (Amazon Web Services, 2015)



It is difficult to value the market for 3D image rendering. It is used in a wide range of applications and analysts include it in a wide range of categories. IDC include 3D image rendering as part of the digital content creation and distribution (DCC&D) category of the HPC market, however rendering is also used in the computer-aid design (CAD), computer-aided engineering (CAE) and mechanical design categories. The DCC&D workload category centers on applications such as 2D and 3D animation, film and video editing and production, and multimedia authoring for media that utilise sophisticated graphics content. HPC is used for image rendering, content management and distribution of finished products for verticals such as film, TV, commercial animation, advertising, architecture gaming, and industrial design. Visual special effects (VFX) and animation for motion pictures and broadcast television (including titles, commercials etc.) require significant amounts of computational capacity. These organisations are driving the use of HPC to create better large-scale games, digital content, animations and visual effects in films (IDC, 2014). As seen in Table 1, IDC anticipated this category to grow in size from US$665m in 2015 to US$858m in 2019 with a CAGR of 7.1%. This is significantly lower than that forecast by Technavio (2012); they forecast the global 3D rendering and virtualization software market to grow at a CAGR of 21.4 percent over the period 2011–2015. One of the key factors contributing to this market growth is the increasing demand from the global entertainment industry (Technavio, 2012).

There are a handful pure-play cloud rendering providers:

i. **GreenButton** was founded as InterGrid in 2006 in New Zealand, to provide small scale customers with a seamless interface to access job processors. GreenButton evolved to develop solutions that allowed industries that need large amounts of compute power to more easily use the cloud to run their compute-intensive workloads without recoding. Starting in the animation sector, GreenButton expanded with vertical applications for financial services and seismic processing. The company had a total turnover of $1.5 million for the fiscal year 2011-12. In May 2014, it was acquired by Microsoft for an undisclosed

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sum and was relaunched as Microsoft Azure Batch. It now exclusively offers Microsoft Azure as a cloud solution. Since being relaunched by Microsoft, GreenButton rendering solutions seem to be limited to Blender although they are pursuing custom solutions more aggressively.

ii. **Zync Render** was a specialist rendering service that provisioned large render jobs for visual effects (VFX) using AWS cloud computing. The founders all worked in VFX production, artistry and software development in the VFX space at companies such as Digital Domain, ILM and GenArts. ZYNC heavily promote the fact that it is designed by VFX artists for VFX artists. By 2014, they had claimed to have worked on over a dozen feature films and hundreds of TV commercials including Star Trek, Transformers, Flight, Looper and more. In August 2014, Google acquired Zync for an undisclosed sum and relaunched it in beta in September 2015. It is limited to image rendering and supports Nuke, Maya, V-Ray and Arnold. It now exclusively offers Google Cloud Platform as a cloud solution.

iii. **Rendicity** is a Cork-based cloud software company that provide a range of cloud solutions for high performance, compute-intensive applications. Operating within a market estimated at €520m, Rendicity's patent-pending technology offers access to infrastructure from Amazon Web Services and Microsoft Azure in an on-demand system. Rendicity is integrated with Maxwell Render and Blender and has recently announced support for Mac OS X in addition to Microsoft Windows.

Primary Research

Introduction

In order to gather insights in to the rendering use case, we used a mixed methods approach including surveys, interviews and desk research. The motivation for this research was to inform commercial positioning for CloudLightning in a rendering use case scenario for Cloud Service Providers. It also informs evaluation criteria for demonstration deployments in later tasks in CloudLightning.

End User Survey

With Rendicity, an Irish SME, DCU contacted 406 end users of rendering software from 29 June to 20 July 2015. End users were identified through Reddit (29.3%), the CGSociety website (26.8%), e-mail (8.1%) and other social networking sites and websites (35.8%). 130 end users completed the survey representing 32% response rate. Demographic data is outlined in Table 1 below. The overwhelming majority of response were from men (95.4%) aged between 25 and 44 (74.0%) with an age range of 18 to 75 and older. The majority of the responses were college educated (68.5%) the majority of which were college educated and employed (53%) or self-employed (35.4%). The respondents represent a wide range of the market including architecture (28.4%), animation (18.5%), visual effects (17.7%). Over 40% of respondents described themselves as animators or designers and over 20% as executive or senior management (incl. owners).

Table 2 Sample demographic data

Demographics	Response Rate (%)
Gender	
Male	95.4
Female	3.1
Age	
18-24	16.9
25-34	41.5
35-44	32.5
45-54	6.9
55-64	2.3
65-74	0
75+	0.77
Location	
European Union	49.1
North America	33.6
South and Central America	6.2
Asia-Pacific	3.9
Other	4.0

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Highest Education Level	
Advanced Graduate Work or PhD	3.9
Master's Degree	16.1
Bachelor's Degree	48.5
Some College	21.5
High School	7.7
Did Not Complete High School	2.3
Employment Status	
Employed	53.0
Self-employed	35.4
A Student	6.2
Out of Work and Looking for Work	3.1
Other	2.3
Company Sector	
Advertising/Media	3.1
Architecture and Architectural Visualisation	28.4
Animation	18.5
Construction	1.5
Education	4
Game Design	6.2
Interior Design	0.8
Health/Medical Imaging	4.6
Mechanical Engineering	4.6
VFX	17.7
Other	20.1
Job Role	
Animator/Designer	40.8
Intern	2.3
IT Director	1.5
Owner/Partner	18.4
Project Manager	5.4
Senior Manager	2.3
Team Lead	8.5
Unemployed	4.6
Other	12.3

The survey confirms desk research that the market is largely made up of SMEs (83.0%). The overwhelming majority of respondents used their own in-hour IT infrastructure for rendering (72.3%). Of those outsourcing rendering, 21.5% use some combination of in-house and outsourced rendering. 5.3% outsource to a render farm with only 3% (4) stating that they use a cloud solution in any form. Reflecting the size of the sample companies, 58.2% spend less than US$1,000 on in-house rendering per month. Average monthly spend on outsourced rendering was significantly lower with the majority of those who responded and knew the approximate amount indicating that they spent less than US$100 per month.

Figure 2 Sample by Number of Employees

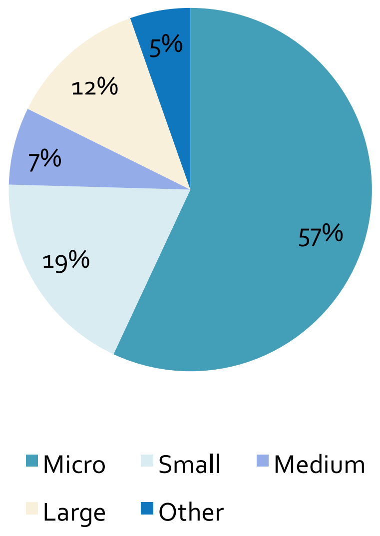


Figure 3. Average Monthly Spend on In-house Rendering

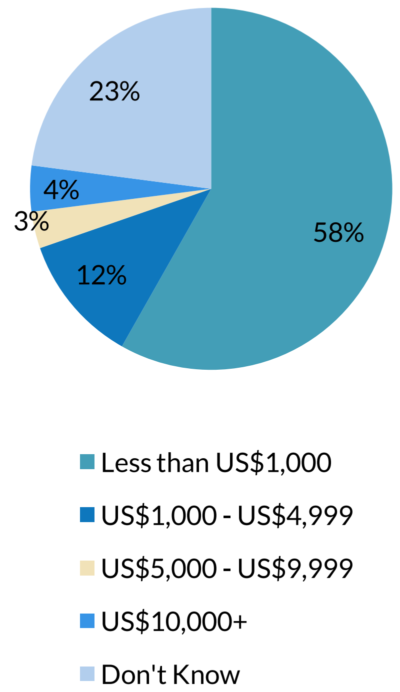
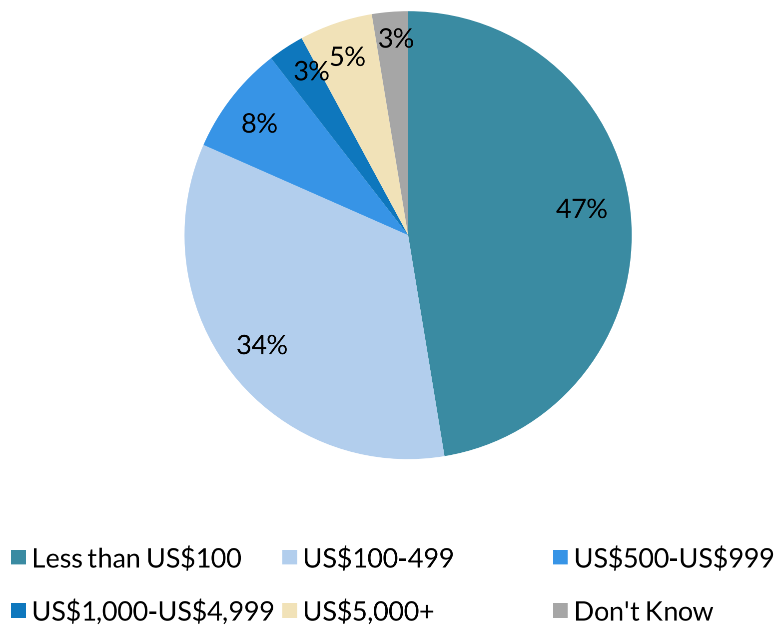


Figure 4 Average Monthly Spend on Outsourced Rendering Activities



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The survey asked respondents what modelling and compositing tools and render engines that they used. They could make more than one selection. Respondents indicated a wide range of software tools, the majority of which were commercial. Render engines reflected the product choices e.g. Blender users used Blender Cycles etc.

Table 3 provides a summary of the main findings. The majority of respondents did not use tools to schedule rendering jobs (58.5%) however those that did used Deadline and Backburner. This is largely reflective of company size and render volumes.

Table 3 Modelling and Compositing Tools and Render Engines Used

Modelling and Compositing Tools		Render Engines	
Product	**%**	**Product**	**%**
3D Studio Max	39.2%	V-Ray	46.9%
Autodesk Maya	33.9%	Mental Ray	35.4%
Blender	30.8%	Blender Cycles	23.9%
Z-Brush	27.7%	Arnold	17.7%
Nuke	25.4%	Maxwell Render	9.2%
Cinema 4D	17.7%	Other	33.1%
SketchUp	10.0%		
Modo	8.5%		
Autodesk Softimage	6.9%		
Revit	6.2%		
Other	25.4%		

44% of the respondents estimated their average input file for rendering being less than 500Mb in size with a further 29% indicating larger file sizes. 24% did not know. The majority rendered less 1,000 frames or images per month (53.1%) with a further 19% rendering 1,000 – 4,999 frames and 22.5% rendering over 5,000 frames or images per month. Averaged render times were typically short reflecting the size of the organisations and volume of rendering; this also explains the high in-house rendering usage (see Figure 5)

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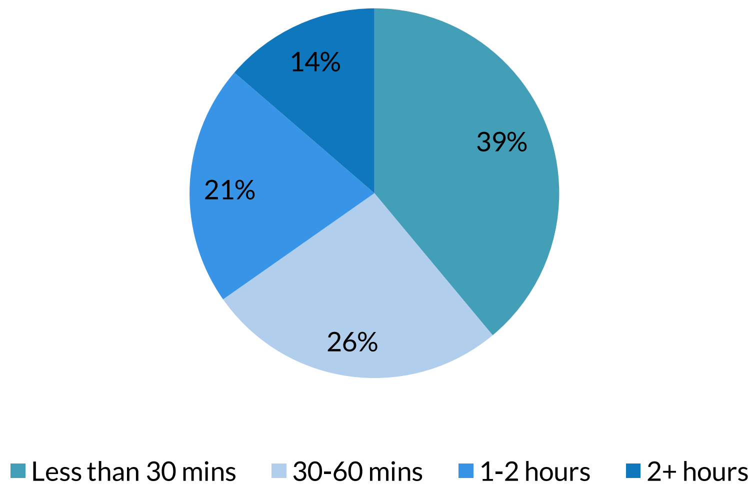
Figure 5. Estimated Average Rendering Time



Respondents were asked to rank seven factors using a 5-point likert scale from *"Not at all important"* to *"Extremely Important"* when using (i) in-house, (ii) outsourced render farms and (iii) cloud rendering services. Across all rendering options, technical reliability was the most important factor (see *Table 4*). For in-house rendering, turnaround time, convenience and ease-of use were also considered important. Unsurprisingly for an internal solution, security and company reputation were not important factors. The rankings for outsourced render farms and cloud rendering services were extremely similar i.e. technical reliability followed by cost and turnaround time. All other factors were considered important.

Table 4 Ranking of Factors Used in Consider Rendering Options

Factor	In-house Rendering	Outsourced Render Farms	Cloud Rendering Services
Technical Reliability	1 (4.20)	1 (4.09)	1 (4.09)
Cost	5 (4.16)	2 (4.08)	2 (4.07)
Turnaround Time	2 (3.90)	3 (4.00)	3 (4.02)
Convenience	3 (3.60)	4 (3.67)	4 (3.67)
Ease of Use	4 (3.18)	5 (3.63)	5 (3.62)
Security	6 (2.69)	6 (3.57)	6 (3.48)
Company's Reputation	7 (2.48)	7 (3.17)	7 (3.01)

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Table 5 Ranking of Agreement with Attitudinal Statements Regarding Rendering

Statement	Ranking
I find the rendering process time-consuming	1 (3.88)
We experience deadline pressure due to rendering time and/or failure rate	2 (3.32)
I think rendering is expensive	3 (3.09)
I have concerns about security and data privacy	4 (2.92)
I can't use my computer while the rendering is taking place	5 (2.82)
Our jobs often fail or crash while rendering	6 (2.30)

These responses are consistent with attitudes towards rendering within their organisations. When asked to ranked their agreement with a number of general attitudinal statements across a 5-point Likert scale (*"Strongly disagree"* to *"Strongly agree"*) respondents indicated that the rendering process within their organisation was time consuming, created deadline pressure and was expensive.

When asked who the decision maker regarding buying or subscribing rendering services, respondents indicated overwhelmingly that the owner/director (72.3%), the project manager (26.95) or IT Manager were the decision makers. Obviously larger organisations were more likely to have project managers or IT managers. Respondents indicated that it usually takes less than a week to make a decision on rendering solutions. This is not surprising as outsourced rendering is typically driven by deadline pressure. The overwhelming majority of respondents indicated that they order online (66.7%) or via telephone (25%). Very few required an in-person meeting.

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End User Interviews

To validate the survey responses, DCU interviewed 12 interviews with Rendicity customers. These customers largely reflect the survey sample with the majority being SMEs. The interviews largely confirmed the survey findings. A number of the interviewees expressed an interest in CPU v GPU benchmarks. A drawbacks of cloud rendering mentioned was file transfer to the cloud for rendering and versioning. The need for local storage of project repositories and support for linked files and data associativity was mentioned by a number of interviewees. There motivation for using the clouds was largely deadline driven. For example:

> *"That was an animation project – rendering a 15-sec little animation for iPhone mobile case manufacturer. And they wanted to show the case, lots of gems flying, very lavish. The main issue we had was the render time, refractions and dispersions of colour you see when you are looking in to a diamond took a long time to render clearly. So we realised half-way through the render process going inside of the diamonds, it suddenly was taking 45 minutes per frame for us and that was far too long so I think we got ten machines for that on Rendicity and rendered it over a few days. We had a deadline and we hit it."*

The predictability of a successful cloud render and predictability of cost were common concerns regarding cloud rendering and specifically the associated expense of cancelled jobs or failed attempts to render. Cloud rendering addressed concerns over scalability and security e.g.:

> *"A lot of farms don't hand the amount we need and the speed we need at. Security ranks high as well as confidentiality. I know that with Amazon I have total control over the servers, whereas I know that with a lot of other services that I have to give out my files and then they render them, I don't know how these files would be handled."*

There was a general perception that using cloud services was difficult and that it required technical knowledge to provision public cloud services for rendering e.g.:

> *"It's got to have a plugin. It should be no more difficult, no, in fact it should be easier to render on a render farm than it is to render on my own hardware. It it's not then it's adding stress and that is not acceptable. There are several render farms out there that I used and they are cost-effective or whatever but they are simply too stressful in experience. I want to click and forget."*

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PRELIMINARY CONCLUSIONS

The gaming, digital content and entertainment sector continues to grow and be driven by the use of HPC to create better large-scale games, digital content, animations and visual effects in films (IDC, 2014). However, the overwhelming majority of organisations in this sector are SMEs. This large base of SMEs (animators, architects, industrial designers) has limited budgets and regular compute-intensive requirements. Cloud penetration for rendering is low and consistent with the findings our general HPC desk research. There are indications of significant market entrants in to the cloud rendering market with both Google and Microsoft making acquisitions in 2014 and Autodesk providing cloud rendering services for a limited number of its 3D animation and CAD products. Few data centres and cloud service providers could be identified that offer specialised rendering services. This therefore represents an opportunity for this segment of the market to differentiate and offer value added services to a broad base of organisations. Based on primary research, evaluation criteria should include ease of use, speed, cost, and scalability. Availability of relevant software libraries will be a key consideration for success in the rendering use case.

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CloudLightning and 3D Image Rendering

As part of the CloudLightning project, we will leverage existing ray tracing libraries optimised for MIC and GPU platforms. We will focus on their use with the CloudLightning environment for rendering sample digital media content with a specific focus on performance of the CloudLightning environment in comparison to standalone cloud configurations. We expect the organisations involved in image processing to benefit through:

- **Energy Efficiency:** we anticipate greater energy efficiency resulting in lower costs for cloud service providers thereby reducing the computation costs associated with provided support for loosely coupled workloads such as 3D image rendering. This will be achieved through the use of heterogeneous computing technologies to offer significantly improved performance/cost and performance/Watt, but also enabling this computation to be hosted at large-scale in the cloud, making it practical for wide-scale use.

- **Speed:** we anticipate that the use of heterogeneous resources can significantly improve 3D image thereby reducing the wider cycle time thus increasing the volume and quality of related outputs. Greater use of the cloud will result in rendering-related downtime and allowing organisations to meet their project deadlines..

- **Reducing complexity:** we anticipate reducing the complexity of service delivery in the cloud through the use of blueprints. This will allow cloud service providers to support the wide range of 3D modelling and specialist image rendering software in the market. The will reduce the barriers to access to infrastructure for smaller organisations in the market.

- **Improved cashflow:** in addition to the costs resulting from energy efficiency, we anticipate that a successful shift to cloud computing, can result in improved cashflow for those organisations for whom 3D image rendering is a core market by transforming expenditure from capital expenditure (CAPEX) to operating expenditure (OPEX). Again, this will help reduce barriers to entry for smaller organisations including animation studios, architects, and visual effects companies amongst others.

- **Reduced CAPEX and IT associated costs:** we anticipate that the use of the cloud, and additional cost efficiencies of the CloudLightning system, will incentivize cloud service providers to support loosely coupled workloads such as 3D image rendering.

- **Extra capacity for overflow ("surge") workloads:** we anticipate that greater use of the cloud and specifically better service delivery, through the use of self-managing and self-organising heterogeneous resources and the ability to scale the system up and down can eliminate rendering bottlenecks and allow cloud service providers to take on more projects with cloud rendering capacity.

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About CloudLightning

CloudLightning is a three-year €4m EU-funded research project to address energy efficiency and high performance in cloud computing. It proposes a novel cloud management and delivery architecture based on the principles of self-organisation and self-management that shifts the deployment and optimisation effort from the consumer to the software stack running on the cloud infrastructure. The goal of the project is to address this inefficient use of resources and consequently to deliver savings to the cloud provider and the cloud consumer in terms of reduced power consumption and improved service delivery, with hyperscale systems particularly in mind. The CloudLightning solution will be demonstrated in the three application domains - genome processing, oil and gas exploration, and ray tracing.

For more information, please visit http://cloudlightning.eu.

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