EDISON

OpGen

Initiation of coverage

Rapid and effective diagnosis of infection

Pharma & biotech

OpGen is a diagnostic company focused on revolutionizing the identification and treatment of bacterial infections. The Acuitas AMR Gene Panel molecular test, in combination with the Acuitas Lighthouse bioinformatics product, allows for the detection of five pathogens as well as 47 resistance genes and mutations, while also predicting the resistance for 14 antibiotics in less than three hours, a major improvement over the two to three days current methods require. OpGen expects to initiate the 510(k) clearance processes for its products in Q219.

Year end	Revenue ($m)	PBT* ($m)	EPS* ($)	DPS ($)	P/E (x)	Yield (%)
12/17	3.2	(15.6)	(9.81)	0.0	N/A	N/A
12/18	2.9	(13.4)	(1.68)	0.0	N/A	N/A
12/19e	4.0	(13.6)	(0.80)	0.0	N/A	N/A
12/20e	5.0	(15.5)	(0.90)	0.0	N/A	N/A

Note: *PBT and EPS are normalised, excluding amortisation of acquired intangibles, exceptional items and share-based payments.

Currently used methods extremely inefficient

It currently takes days to test a patient sample to find out if they have an infection, what they are infected with and to which drugs that infection might be susceptible. This can lead to a delay in treatment or the wrong treatment being prescribed. According to the Centers for Disease Control and Prevention (CDC), there are over two million cases of drug-resistant bacterial infections every year, so identifying the correct treatment is more important than ever.

Hours instead of days

In less than three hours, OpGen's system can do what current systems take two to three days to achieve. The company will first file for approval for testing in bacterial isolates in early Q219, then follow up with an application to test directly from urine samples in Q419 and another for its Lighthouse software in H219. It will first focus on complicated urinary tract infections (cUTI), of which there are around one million cases per year.

A public health platform

OpGen announced a collaboration with the New York State Department of Health and Merck's ILUM Health Solutions to develop a tool to track infectious disease and antimicrobial resistance across New York State. Through this agreement, OpGen will gain access to hospitals across New York, which will increase product penetration. The company will receive $1.6m over the first 12 months during the demonstration portion, with full implementation expected over the next five years.

Valuation: $47.3m or $2.68 per share

We arrive at a valuation of $47.3m or $2.68 per basic share (post Q119 equity offering), driven mainly by the Acuitas AMR Gene Panel and Lighthouse products. Key valuation inflection points over the next 12–18 months will be FDA 510(k) clearances for both key products as well as the subsequent commercial launch. We expect the company to require $41m in financing before profitability in 2023.

15 April 2019

Price	**US$0.59**
Market cap	**US$10m**

Net cash ($m) at 31 December 2018	3.5
Shares in issue (post offering)	17.6m
Free float	93.8%
Code	OPGN
Primary exchange	Nasdaq
Secondary exchange	N/A

Share price performance

%	1m	3m	12m
Abs	(54.6)	(66.2)	(68.7)
Rel (local)	(56.5)	(69.8)	(71.3)

52-week high/low	US$2.8	US$0.6

Business description

OpGen is a diagnostic company focused on revolutionizing the identification and treatment of bacterial infections. The Acuitas AMR Gene Panel molecular test, in combination with the Acuitas Lighthouse bioinformatics product, detects multiple pathogens and predicts antibiotic resistance in less than three hours, a major improvement on the two to three days that current methods require.

Next events

Acuitas Gene Panel (isolates) 510(k) filing	Q219
Acuitas Gene Panel (urine) 510(k) filing	Q419
Acuitas Lighthouse 510(k) filing	H219

Analysts

Maxim Jacobs	+1 646 653 7027
Briana Warschun	+1 646 653 7031

healthcare@edisongroup.com

Edison profile page

Investment summary

Company description: Combating drug-resistant infections

OpGen is a US-based precision medicine company, which is attempting to use its proprietary platform to fight drug-resistant infections. OpGen's chairman and CEO is Evan Jones, a molecular diagnostics industry veteran, who had been previously the CEO of Digene, which was sold for $1.6bn to Qiagen. OpGen's main focus is the Acuitas AMR Gene Panel molecular test and the Acuitas Lighthouse bioinformatics product, which allow for the detection of five pathogens as well as 47 resistance genes and mutations, while also predicting resistance across nine different antibiotic classes in less than three hours, a major improvement over the two to three days that current methods require. OpGen expects to file a 510(k) application with the FDA for the AMR Gene Panel in early Q219 and follow up with an application to test directly from urine samples in Q419. It also expects to file a 510(k) for its Lighthouse software in H219. Assuming six-month review times, OpGen should have a full suite of products necessary for its commercial launch available in H120.

Valuation: $47.3m or $2.68 per share

We arrive at an initial valuation of $47.3m or $2.68 per basic share, which is based on a series of assumptions about the key components of the company's platform, namely the Acuitas Gene Panel and Lighthouse products. We assign a 40% probability of commercial success, which blends FDA and commercial risk in equal proportion. While 510(k) applications typically have high clearance rates (85% in 2018), *De Novo* 510(k) applications (which the Gene Panel test for urine samples and Lighthouse software are) are cleared at a lower rate (64% in 2018). The commercial risk stems from the fact that this is a competitive area so an additional risk parameter is warranted. We estimate $174m in peak sales, which represents penetration into around 10% of hospitals.

Financials: Funding needed for commercialization

OpGen reported $4.6m in cash and cash equivalents at the end of 2018 and raised an additional $5.0m in net proceeds in an equity offering in late March (gross proceeds of $5.4m through the sale of 9m shares at $0.60/share), which is enough to fund the company into Q419. We model an additional $5m worth of financing for 2019, and $41m in total through to profitability in 2023.

Sensitivities: Regulatory and commercial risks

In the near term, the key risk for OpGen is regulatory as it will need to have three separate 510(k) clearances, starting with the AMR Gene Panel in bacterial isolates (ie samples that have already been cultured), moving on to a *De Novo* 510(k) clearance to test directly from a urine sample and culminating in another *De Novo* 510(k) clearance for its Lighthouse bioinformatics software to analyze the data. 510(k) applications typically have a very high success rate of around 85% with six-month review times but the approval rate is lower (64% in 2018) and the review time longer for *De Novo* 510(k) applications (typically eight to nine months). While the regulatory risk is not particularly high, it is not to be ignored either. There are also commercial risks. The main customers for OpGen's products are hospitals, which are notorious for long sell cycles and cost sensitivity. Also, clinical pathology is a very competitive area in which OpGen will be competing with a number of established players and new entrants. The Acuitas AMR Gene Panel, in combination with the Acuitas Lighthouse software, appears to provide a best-in-class product, especially with regards to the cUTI market. However, best in class does not always win the day in gaining accounts. There is also intellectual property risk. There are no issued patents related to the Acuitas products, although three are currently pending. OpGen plans to file additional patents, but until patents are issued it is hard to tell exactly what the intellectual property-based barriers to entry are. Of course, there are other barriers, such as know-how.

Company description: A powerful platform

OpGen was founded in 2001 and publicly listed in the US in 2015. The company has three main product lines/families including legacy FISH tests (which they acquired through a merger with AdvandDx in 2015) currently on the market and approved for use in the US and EU, the Acuitas AMR Gene Panel and Acuitas Lighthouse bioinformatics system.

Exhibit 1: OpGen products

Product	Description	Status	Next milestone
QuickFISH and PNA FISH products	12 legacy QuickFISH and PNA FISH products, which are used for the rapid detection and identification of various pathogens, including Staphylococcus, Enterococcus, Gram-negative bacteria and Candida, with pathogen identification and differentiation information coming 20–90 minutes after positive blood culture results. FDA cleared and CE marked.	On market	Ongoing sales
Acuitas AMR Gene Panel	Provides microbial identification and antibiotic resistance information.	Available on the market for research use only (RUO).	510(k) application in bacterial isolates expected in Q219 and *De Novo* 510(k) for urine in Q419.
Acuitas Lighthouse	Bioinformatics platform that combines Gene Panel test results with patient and hospital information to help manage drug-resistant infections and predict resistance to nine classes of antibiotics.	Not available commercially	*De Novo* 510(k) application in H219

Source: OpGen

Finding a solution to increasingly problematic infections

Drug-resistant infections are increasingly becoming a problem, with more than two million cases per year and over 23,000 deaths in the US according to the CDC (see Exhibit 2). Some, such as certain strains of Carbapenem-resistant Enterobacteriaceae (CRE), have developed resistance to nearly all antibiotics. By 2050, the number of deaths attributable to antimicrobial resistance could grow to 317,000 per year in the US alone.[1]

Exhibit 2: Antibiotic resistant bacteria

Antibiotic-resistant microorganism	CDC threat level	Infections included in case total	Annual cases	Annual deaths
Carbapenem-resistant Enterobacteriaceae (CRE)	Urgent	Healthcare-associated infections (HAIs) caused by Klebsiella and E. coli with onset in hospitalized patients	9,300	610
Drug-resistant Neisseria gonorrhoeae	Urgent	All infections	246,000	<5
Multidrug-resistant Acinetobacter	Serious		7,300	500
Drug-resistant Campylobacter (azithromycin or ciprofloxacin)	Serious	All infections	310,000	28
Drug-resistant Candida (fluconazole)	Serious	HAIs with onset in hospitalized patients	3,400	220
Extended-spectrum β-lactamase producing Enterobacteriaceae (ESBLs)	Serious	HAIs caused by Klebsiella and E. coli with onset in hospitalized patients	26,000	1,700
Vancomycin-resistant Enterococcus (VRE)	Serious	HAIs with onset in hospitalized patients	20,000	1,300
Multidrug-resistant Pseudomonas aeruginosa (three or more drug classes)	Serious	HAIs with onset in hospitalized patients	6,700	440
Drug-resistant non-typhoidal Salmonella (ceftriaxone, ciprofloxacin or 5 or more drug classes)	Serious	All infections	100,000	40
Drug-resistant Salmonella Typhi	Serious	All infections	3,800	<5
Drug-resistant Shigella (azithromycin or ciprofloxacin)	Serious	All infections	27,000	<5
Methicillin-resistant Staphylococcus aureus (MRSA)	Serious	Invasive infections	80,000	11,000
Streptococcus pneumonia (full resistance to clinically relevant drugs)	Serious	All infections	1,200,000	7,000
Drug-resistant tuberculosis (any clinically relevant drug)	Serious	All infections	1,042	50
Vancomycin-resistant Staphylococcus aureus (VRSA)	Concerning	All infections	<5	<5
Erythromycin-resistant Group A Streptococcus	Concerning	Invasive infections	1,300	160
Clindamycin-resistant Group B Streptococcus	Concerning	Invasive infections	7,600	440
Summary for antibiotic resistant infections			2,049,442	23,488

Source: CDC

1 Review on Antimicrobial Resistance. Antimicrobial Resistance: Tackling a Crisis for the Health and Wealth of Nations. 2014. Chaired by Jim O'Neill.

Also, whether drug-resistant or not, hospital-acquired infections (HAIs) cost hospitals around $10bn a year, with the drug-resistant variety associated with a much longer length of stay and hence, cost. For example, methicillin-resistant Staphylococcus aureus (MRSA) related surgical site infections add more than $20,000 in cost over regular surgical site infections and add almost 12 days to the length of stay (see Exhibit 3).[2]

Exhibit 3: Costs of treating certain hospital-associated infections

Type of infection	Cost ($)	Length of stay (days)
Surgical site infections	$20,785	11.2
Surgical site infections - MRSA	$42,300	23.0
Central line bloodstream infections	$45,814	10.4
Central line bloodstream infections - MRSA	$58,614	15.7

Source: Zimlichman et al., Health Care-Associated Infections: A Meta-analysis of Costs and Financial Impact on the US Health Care System. *JAMA Internal Medicine*. 2013 Dec 9-23; 173(22): 2039-46.

While new classes of antibiotics do help, that help is temporary as resistant strains are identified just a few years after a new antibiotic is introduced. Therefore, the best way to minimize the impact of infections in the long term is faster identification of the pathogen and any potential resistance so that the correct antibiotic can be administered from the beginning. This helps reduce the amount of time that the patient is affected by the infection (according to one study in patients with septic shock, every hour that effective antimicrobial therapy is delayed reduces survival by 7.6%[3]) and reduces the risk that the infection spreads to other patients.

The OpGen solution

OpGen has a two-pronged approach: the Acuitas AMR Gene Panel identifies five pathogens and 47 resistance genes and mutations, while the Acuitas Lighthouse bioinformatics system predicts the resistance to 14 antibiotics based on information obtained from the Merck SMART Pathogen Archive (which has more than 250,000 samples), thousands of pathogens from hospitals and patient hospital data.

Exhibit 4: Acuitis AMR Gene Panel

Source: OpGen

2 Zimlichman et al., Health Care-Associated Infections: A Meta-analysis of Costs and Financial Impact on the US Health Care System. *JAMA Internal Medicine*. 2013 Dec 9-23; 173(22): 2039-46.

3 Kumar et al., Duration of hypotension before initiation of effective antimicrobial therapy is the critical determinant of survival in human septic shock. Critical Care Medicine. 2006 Jun; 34(6): 1589-96.

The Acuitas AMR Gene Panel is a qualitative and semi-quantitative nucleic acid-based in vitro diagnostic test that is currently optimized for the cUTI market, which will be the initial focus commercially, as the five pathogens it detects (namely *E. coli, E. faecalis, K. pneumoniae, P. mirabilis* and *P. aeruginosa*) represent approximately 88% of all cUTIs.[4] Importantly, the test is able to detect resistance genes regardless of the original pathogen, so the resistance data are not limited to the five target pathogens.

The company announced in February that it has completed the clinical trials necessary for its first 510(k) submission for the Acuitas AMR Gene Panel in bacterial isolates, which is currently expected to occur in early Q219. In total, the company tested over 1,000 isolates at four sites. This will be a standard 510(k) submission and typically the FDA takes around six months to review a 510(k) and the clearance rate has historically been around 85%, according to FDA statistics. We believe there is a high probability of clearance, especially as previously released data in 417 samples indicated that the test correctly identified the pathogen species in 99.5% of cases.

The initial clearance will be in bacterial isolates, which have already been cultured from the original sample that may be blood, urine etc. OpGen expects to file a follow-on *De Novo* 510(k) submission in Q419. The difference between a standard 510(k) submission and a *De Novo* 510(k) submission is that the *De Novo* pathway is for devices that do not have a valid predicate. *De Novo* applications are associated with somewhat lower clearance rates and longer review periods. Clearance of this application would allow for testing directly from urine so that the results would not require a sample to be cultured (which can add 15+ hours to the process) and OpGen can truly differentiate itself from current methods (as well as the newer molecular entrants, which also typically depend on the samples already being cultured) by providing an answer in three hours. A direct from urine sample is especially important as the company will initially focus on urinary tract infections. That application will be based on 1,500 fresh urine samples and around 300 contrived urine samples at a total of five to eight sites.

While the Acuitas AMR Gene Panel is a sound product on its own, what truly differentiates the OpGen solution from others is the Acuitas Lighthouse software. Lighthouse is cloud-hosted and includes a few key components: the Acuitas Lighthouse portal, which is a web application, the Acuitas Lighthouse Prediction Engine, data analysis software that draws from Lighthouse Knowledgebase, a relational database management system. Data from the Acuitas AMR Gene Panel is input into the Lighthouse portal and the Prediction Engine component indicates whether there is evidence of resistance due to the presence of certain genes and if there is any known intrinsic resistance to certain drugs (up to 14 antibiotics across nine antibiotic classes, including Aminoglycosides, Carbapenems, Cephalosporins, Fluoroquinolones, Polymyxins, Penicillins, Sulfonamides, Trimethoprim and Vancomycin). The final results are reported in a Prediction Report and the Resistance Dashboard interface in the portal.

A key foundation of the Lighthouse system is the Lighthouse Knowledgebase, populated by data from the Merck Study for Monitoring Antimicrobial Resistance Trends (SMART) archive, which has collected more than 250,000 bacterial pathogens over the last 15+ years as well as thousands of additional pathogens from other sources. Importantly, the Knowledgebase is constantly growing, as every time the test is used, data from that specific case of infection are added to it. As the Knowledgebase grows, we would expect the Lighthouse Prediction Engine to make better predictions over time.

In order to be commercialized broadly, the AMR Prediction Engine would need to obtain an FDA *De Novo* 510(k) clearance and we expect a submission in H219. The total data set that will be submitted to the FDA will include 2,000 representative isolates, 1,500 urine samples and resulting isolates, and around 300 contrived urine samples. Based on data that have been disclosed (see

4 Flores-Mireles et al., Urinary tract infections: epidemiology, mechanisms of infection and treatment options. *Nature Reviews Microbiology.* 2015 May; 13(5): 269–284.

Exhibit 5), the Prediction Engine has a sensitivity of 90–91% (ie a 9–10% false negative rate) and a specificity of 83–90% (ie a 10–17% false positive rate), which from our experience indicates that the Prediction Engine is relatively accurate.

Exhibit 5: Acuitas Lighthouse Prediction Engine training data set

	Sensitivity	Specificity	Accuracy	Positive predictive value (PPV)	Negative predictive value (NPV)
E.coli	91%	90%	91%	94%	85%
K. pneumoniae	90%	83%	88%	93%	68%

Source: Walker et al., Predicting Antibiotic Resistance in Gram-Negative Bacilli from Resistance Genes. *Antimicrobial Agents and Chemotherapy.* 63:e02462-18. Opgen.

OpGen also currently markets 12 QuickFISH and PNA FISH products, which are used for the identification of various pathogens, including Staphylococcus, Enterococcus, Gram-negative bacteria and Candida, with pathogen identification and differentiation information coming 20–90 minutes after positive blood culture results. Approximately 70 accounts, including academic medical centres, tertiary care hospitals and community hospitals, have purchased FISH products over the previous 12 months, and we would expect these to be some of the first candidates to purchase the Acuitas family of products once 510(k) clearances are granted.

New York Department of Health Initiative

A key test of the use of the Acuitas AMR Gene Panel and Lighthouse software will be in New York State. In September, OpGen announced a collaboration with the New York State Department of Health and Merck's ILUM Health Solutions (the collaboration is called the New York State Infectious Disease Digital Health Initiative) to develop a tool to detect, track and manage infectious disease and antimicrobial resistance across the state. Importantly, this collaboration is not dependent on any FDA approval as it is considered to be a research use.

The first portion is a 12-month development project in which OpGen will work with the Department of Health's Wadsworth Center and ILUM to develop an infectious disease tracking platform that connects hospitals to the Department of Health to facilitate state-wide surveillance. The company will receive $1.6m over the first 12 months during the demonstration portion, which has already started, with full implementation in New York State's more than 170 hospitals expected over the next five years. Currently, Acuitas Lighthouse software and Gene Panel systems are being installed in three tier 1 health systems in the New York metropolitan area. These systems comprise 35 hospitals and total 12,000 beds. Depending on the outcome of this collaboration, additional states may come up with their own similar surveillance initiatives, which could accelerate the commercial adoption of OpGen's systems.

Commercial focus

As mentioned previously, once the Acuitas AMR Gene Panel and Lighthouse products receive 510(k) clearances, the initial commercial focus for OpGen will be the cUTI market. A cUTI is a urinary tract infection where there are factors compromising either the urinary tract itself or host defence. In the US, there are approximately one million cases of cUTI per year, with 70–80% attributable to indwelling catheters found in hospitals.[5] Catheter-associated cUTIs are the most common type of healthcare-associated infection, representing over 30% of the total reported to the CDC's National Healthcare Safety Network. These infections often occur due to the formation of biofilms on the surfaces of catheter and collecting systems, with the source being either rectal or vaginal colonization or the contaminated hands of medical personnel. There are 13,000 deaths

5 Flores-Mireles et al., Urinary tract infections: epidemiology, mechanisms of infection and treatment options. *Nature Reviews Microbiology*. 2015 May; 13(5): 269–284.

involving catheter-associated cUTIs, which also add two to four days on average to the length of stay in the hospital.[6]

These catheter-associated cUTIs can become serious because of the risk of Urosepsis, which accounts for approximately 25% of all sepsis cases annually and is associated with up to 20–42% mortality.[7] Treatment is also becoming more complicated as resistance rates are increasing dramatically. 14% are Extended-spectrum β-lactamase resistant (ESBL), which means there is resistance to third-generation cephalosporin antibiotics and that last resort carbapenem or restricted antibiotics need to be used in these patients. Additionally, 35% are resistant to fluoroquinolones.[8]

It is therefore relatively clear why OpGen has decided to focus on the cUTI market initially. It is a massive problem at hospitals (which, besides dealing with the infection itself, also have to pay the bill because the infection was hospital acquired), increasingly difficult to treat and is typically diagnosed with urine samples. Over time, OpGen expects to expand its focus to other indications with lower respiratory infections (including pneumonia), as this is a major problem at hospitals. Hospital-acquired pneumonia is the most frequent hospital-acquired infection in intensive care units and, while not as frequent as catheter-associated cUTIs, is associated with higher morbidity, mortality and cost.[9] However, OpGen would first need to come up with a new Gene Panel product with different pathogens (since pneumonia-associated pathogens often differ from those associated with cUTI, although there would be some overlap as *P. aeruginosa* and *K. pneumoniae* are also common in hospital acquired pneumonia cases[10]) and ideally one that can analyze sputum samples, the primary sample method for detecting pneumonia, although samples could be analysed via the bacterial isolates route.

Competitive landscape

OpGen faces two types of competitors: traditional culture-based competitors that provide a lot of information over several days and the molecular diagnostic players that provide less information, more quickly.

6 Catheter-associated Urinary Tract Infection (CAUTI) Toolkit by Carolyn Gould, MD, Division of Healthcare Quality Promotion, CDC.

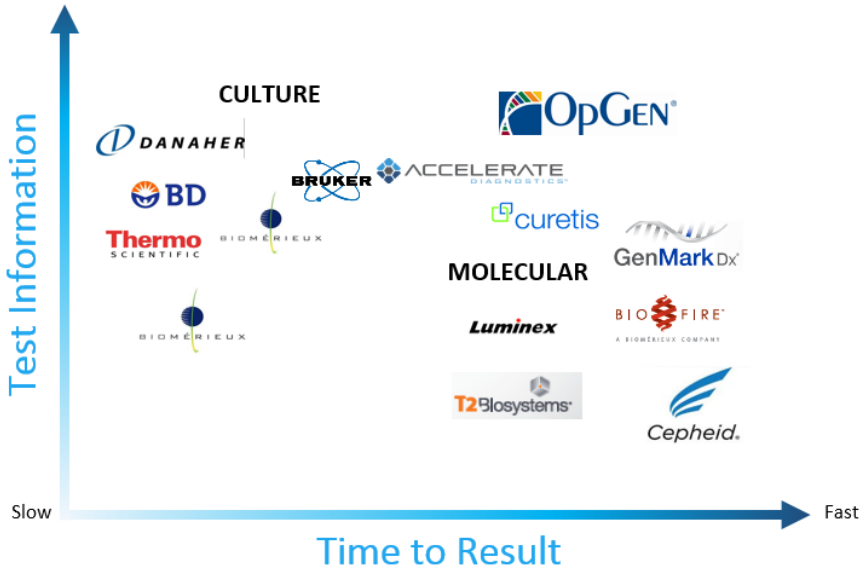
7 Wagenlehner et al., Therapeutic challenges of urosepsis. European Journal of Clinical Investigation 2008; 38(S2):45-49.

8 Lob et al., Susceptibility patterns and ESBL rates of Escherichia coli from urinary tract infections in Canada and the United States, SMART 2010–2014. *Diagnostic Microbiology and Infectious Disease.* Volume 85, Issue 4, August 2016, Pages 459-465.

9 Alp et al., Incidence, risk factors and mortality of nosocomial pneumonia in Intensive Care Units: A prospective study. *Annals of Clinical Microbiology and Antimicrobials* 2004, 3:17

10 Alp et al., Incidence, risk factors and mortality of nosocomial pneumonia in Intensive Care Units: A prospective study. *Annals of Clinical Microbiology and Antimicrobials* 2004, 3:17

Exhibit 6: Competitive landscape



Source: OpGen

If OpGen were simply marketing the Acuitas AMR Gene Panel, it would probably be positioned squarely in the middle of the molecular players, sacrificing the amount of information provided for speed. Typically, it has been focused on pathogen identification, with antibiotic susceptibility information having to come from traditional methods, which can take days. What sets OpGen apart and makes its offering arguably the best of both worlds (the amount of information of a culture-based method in the time of a molecular-based method) is the Acuitas Lighthouse software, which also provides an antibiotic resistance prediction in three hours. Also, other than Curetis, competitors are typically not specifically focused on the cUTI market, instead focusing on generic blood culture identification or Gram-negative bacteria or broader areas such as sepsis. Despite the competition, given that it is still early days in this market, OpGen certainly has a chance to gain a decent foothold. The only things OpGen's products are missing versus the competition are real world cost-benefit studies where usage of OpGen's suite of products helps reduce hospital costs. These take time but will help adoption once in hand.

Exhibit 7: OpGen vs molecular peers

Company	Market cap	Product	Sales (division/company)	Information	Timing	Comments
OpGen	$10.8m	Acuitas	$2.9m in company sales	Five pathogens and 47 resistance genes, and antibiotic resistance information for 14 antibiotics	3 hours	Focused both on pathogen identification and prediction of antibiotic resistance. Initial approval will be in bacterial isolates, but will expand to direct from sample with urine test.
BioMerieux	$8.6bn	BioFire FilmArray Blood Culture Identification Panel	€483m in 2018 for BioFire division	24 gram-positive, gram-negative and yeast pathogens as well as three antibiotic resistance genes	3 hours	Focus mainly on pathogen identification, depends on blood culture. No benefit in antibiotic susceptibility testing timing
Curetis	$29.3m	Unyvero A50	€1.6m in annualized company sales	88 pathogens, 15 resistance genes (UTI panel))	4-5 hours	Direct from specimen, no culturing required. Launched Unyvero platform in the US in 2018.
Genmark Diagnostics	$395.9m	ePlex	$70.8m in 2018 company sales	12 gram-positive organisms and three antibiotic resistance genes	2 hours	Focused on pathogen identification. Depends on blood culture. Gram-positive test approved in 2018 and Gram-negative test expected in 2019.
Luminex	$1.1bn	Gram-Negative Blood Culture test	$216m in 2018 company sales	Four species, 4 genus and 6 antibiotic resistance genes	2 hours	Focused on pathogen identification. Depends on blood culture.
T2 Biosystems	$110.5m	T2Bacteria	$10.5m in company sales	Five pathogens	3-5 hours	Focused on pathogen identification. Depends on blood culture.
Danaher	$88.4bn	Cepheid Xpert MRSA/SA BC	$1.7bn for Diagnositcs division	Two pathogens	1 hour	Focused on pathogen identification. Depends on blood culture.
Accelerate Diagnostics	$1.1bn	Pheno	$5.7m in 2018 company sales	140 assays	1.5 hours for ID and <7 hours for antibiotic susceptibility	Depends on blood culture.

Source: Company reports

Assumptions and projections

According to the American Hospital Association, there are around 6,200 hospitals in the US. OpGen currently has a very small sales and marketing team, which handles around 80 accounts (mainly for the legacy FISH-based tests) and, while the company will certainly grow its commercial organization after 510(k) clearance, it is unlikely that it will grow enough to penetrate every hospital in the country. In our projections, we therefore assume it will penetrate less than 7% of hospitals by 2025 with its Acuitas family of tests (up from the ~12 hospitals currently penetrated and the 40 we expect to be penetrated in 2020) though we do expect the company to focus on the larger hospitals so that 7% will be associated with a larger percentage of the total number of cUTIs in the country (the top 24% of hospitals are associated with 57% of the beds according to the American Hospital Association). We also expect the company to expand its focus over time beyond the cUTI market as we note that the initial Gene Panel 510(k) application in bacterial isolates is not indication specific so the test could be used across diseases and the New York State Infectious Disease Digital Health Initiative is focused broadly on infectious disease across hospitals in the state.

Pricing has not been finalized, but we assume that equipment will be leased at approximately $20,000 per unit per year. We also assume approximately 1,000 tests per hospital at peak although we expect far fewer per hospital in the near term (100 in 2019 and 300 in 2020). We estimate pricing at $175 per test as the company has suggested a $150–200 average selling price (ASP) covering both Gene Panel and Lighthouse. This pricing assumption seems very reasonable as the current procedural terminology (CPT) codes in the emergency room (note there would not be reimbursement in the in-patient hospital setting as infection costs are bundled) should provide around $220 per test according to T2 Biosystems' analysis. We also assume that average pricing will increase at 4% per year. Based on these assumptions, we project $76.8m in revenues in 2025, growing to $174.1m in 2040.

Note that we are currently not estimating any revenues outside the US as OpGen's management is domestically focused at present. However, the company did announce a contract from the CDC to develop smartphone-based solutions for infection control in low and middle income countries. In

partnership with Merck's ILUM Health Solutions (with which it is also partnered for the New York State Infectious Disease Digital Health Initiative), software was deployed in three sites in Colombia and OpGen is in discussions to establish a distribution relationship for South America. If the company becomes more active globally, we may need to increase our estimates accordingly.

Sensitivities

In the near term, the key risk for OpGen is regulatory. To maximize its commercial opportunity, it will need to have three separate 510(k) clearances, starting with the AMR Gene Panel in bacterial isolates (ie samples that have already been cultured), moving on to a *De Novo* 510(k clearance to test directly from a urine sample and culminating in a *De Novo* 510(k) clearance for its Lighthouse bioinformatics software to analyze the data. 510(k) applications typically have a very high success rate of around 85% and relatively short review times of around six months, but the approval rate is lower (64% in 2018) and the review time longer for *De Novo* 510(k) applications (typically eight to nine). While the regulatory risk is not particularly high, it is not to be ignored either and could have a major impact on near-term forecasts.

There are also commercial risks. The main customers for OpGen's products are hospitals, which are notorious for long sell cycles and cost sensitivity. However, hospital-acquired infections (HAIs) are a large financial burden, with the cost being borne by the hospitals. The total cost of HAIs is estimated to be $10bn across the US, according to a 2013 study published in the Journal of the American Medical Association (JAMA). Hence, any technology which will help limit the impact of HAIs by reducing length of stay, as well as minimizing the risk of further complications, may be welcome. Also, agreements with state departments of health (like the partnership with the New York State Department of Health) will help facilitate access to a number of state hospital systems. Another commercial risk is the fact that clinical pathology is a very competitive area where OpGen will be vying with a number of established players and new entrants. In combination with the Acuitas Lighthouse software, the Acuitas AMR Gene Panel appears to provide a best-in-class product, especially with regards to the cUTI market. However, best in class does not always win the day in gaining accounts as some hospitals may simply have existing relationships with some of the larger competitors. It is important to note that this is not the first time around for Evan Jones, chairman and CEO of OpGen. He is a highly experienced molecular diagnostics industry veteran, with a 16-year tenure as CEO of Digene, which was sold for $1.6bn to Qiagen. He was also on the board of Foundation Medicine until its acquisition by Roche in 2018 for $5.3 bilion and currently serves on the board of Veracyte.

There also is intellectual property risk. While the company has ownership rights to eight issued and three pending patents relating to its FISH products, there are no issued patents relating to the Acuitas products, although three are currently pending. The company does plan to file additional patents, but until patents are issued it is hard to tell what exactly the intellectual property-based barriers to entry are. Of course, there are other barriers, such as know-how. Even without patents it would be extremely difficult to replicate the Lighthouse Prediction Engine as its performance is based on the large number of inputs it has already received from the Merck SMART database and tests already performed by the company. Also, we would expect OpGen to continuously innovate the Lighthouse product, making it and its performance a bit of a moving target.

Finally, there is heavy dilution risk due to the current market capitalization of the company. Historically, OpGen has raised equity that has been relatively expensive and quite dilutive. The public offering in March raised $5.4m in gross proceeds ($5.0m net) through the issuance of 9.0m shares (over half of the current total) at a greater than 30% discount to the previous day's stock price.

Valuation

We arrive at an initial valuation of $47.3m or $2.68 per basic share, which is based on a series of assumptions about the key components of the company's platform, namely the Acuitas Gene Panel and Lighthouse products.

We assign a 40% probability of commercial success, which blends FDA and commercial risk in equal proportion, roughly around 60% each. While 510(k) applications typically have high clearance rates (85% in 2018), *De Novo* 510(k) applications (which the Gene Panel test for urine samples and Lighthouse software are) are cleared at a lower rate (64% in 2018). The commercial risk stems from the fact that this is a competitive area so an additional risk parameter is warranted.

For the legacy FISH business, we model a 5% annual decline in perpetuity as sales have been falling and this line of business will be less of a focus going forward (although there is a chance it could grow as OpGen gains more accounts for the Acuitas products). As mentioned previously, for the Acuitas products we estimate around 10% peak penetration in hospitals, with around 1,000 tests per hospital and pricing that starts at $175 per test (although we have pricing increasing at 4% per year).

We expect gross margin to improve to 70% over time as volumes increase and for sales and marketing expenses to ramp considerably from $1.5m in 2018 to around $10m by 2022. R&D should continue to grow gradually as OpGen continues to innovate additional Gene Panel tests, as well as the Lighthouse program.

All this was modelled using a risk-adjusted NPV model with a 12.5% discount rate, which runs through 2040. We chose 2040 simply because we expect additional patents to be filed in the next year or so, which would extend patent protection until at least 2040. Beyond any patent protection, we expect know-how to be a major barrier to entry for any competitor, especially with regards to the Lighthouse software, which we expect to constantly be improved (we project continued R&D spend through to 2040 as continuous innovation will likely be required to stay ahead of competition).

Exhibit 8: OpGen valuation table

Product	Main Indication	Status	Probability of successful commercialization	Launch year	Peak sales ($m)	Patent protection	Economics	rNPV ($m)
OpGen Diagnostic Platform	cUTI, lower respiratory	Market (RUO)/registration	40%	2019	174	2039	100.0%	38.8
Total								38.8
Net Cash (Q418 + pro-forma proceeds from Q119 offering)								8.5
Total firm value								**47.3**
Total basic shares (m) - post Q119 offering (estimated)								17.6
Value per basic share ($)								**2.68**
Options (Q418, m)								3.7
Total number of shares (m)								21.4
Diluted value per share ($)								2.21

Source: Edison Investment Research

One item that deserves some discussion is the number of options outstanding. On the face of it, if the 3.7m options and warrants are exercised, this would lead to around 17% dilution. However, the majority of these options are well out of the money and may expire before the stock reaches the exercise price (see Exhibit 9). The company also has more than 200,000 stock options with a weighted average exercise price of $20.58. In other words, there would need to be significant appreciation in the stock price before any dilution from these warrants or options is felt by investors.

Exhibit 9: OpGen warrants

Number of warrants	Exercise price	Expiration date
495,026	$70.57*	Nov-19 to Feb-25
1,000,003	$10.625	Jul-22
184,615	$4.06	Feb-23
1,846,153	$3.25	Feb-23

Source: OpGen. Note: *$70.57 is the weighted average exercise price of the warrants.

Financials

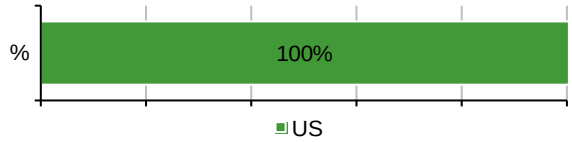
OpGen's 2018 post-tax loss was $13.4m, down from a loss of $15.4m in 2017, with the decline mainly attributable to reduced operating expenses, namely R&D expenses, which fell from $6.9m to $5.7m, and sales and marketing expenses, which decreased from $2.8m to $1.5m. For 2019, we expect total revenue to grow from $2.9m in 2018 to $4.0m, with the growth mainly due to revenue associated with the New York State Infectious Disease Digital Health Initiative (currently expected to be $1.6m in the first 12 months).

OpGen reported $4.6m in cash and cash equivalents at the end of 2018, and raised an additional $5.0m in net proceeds in an equity offering in late March (gross proceeds of $5.4m through the sale of 9m shares at $0.60/share), which we believe is enough to fund the company into Q419. We model an additional $5m worth of financing for 2019, and $41m in total through to profitability in 2023. Per Edison policy, we assume future financings are to be funded with debt.

Exhibit 10: Financial summary

$'000s	2017	2018	2019e	2020e
Year end 31 December	GAAP	GAAP	GAAP	GAAP
PROFIT & LOSS				
Revenue	3,211	2,946	4,010	5,032
Cost of Sales	(2,133)	(1,848)	(2,005)	(1,902)
Gross Profit	1,078	1,098	2,005	3,130
Sales, General and Administrative Expenses	(9,460)	(8,601)	(9,500)	(12,280)
Research and Development Expense	(6,883)	(5,677)	(5,904)	(6,141)
EBITDA	(15,266)	(13,180)	(13,399)	(15,290)
Operating Profit (before amort. and except.)	(15,266)	(13,180)	(13,399)	(15,290)
Intangible Amortisation	0	0	0	0
Other	0	0	0	0
Exceptionals	0	0	0	0
Operating Profit	(15,266)	(13,180)	(13,399)	(15,290)
Net Interest	(321)	(186)	(193)	(201)
Other	167	(2)	0	0
Profit Before Tax (norm)	(15,587)	(13,366)	(13,593)	(15,491)
Profit Before Tax (FRS 3)	(15,419)	(13,368)	(13,593)	(15,491)
Tax	0	0	0	0
Deferred tax	(0)	(0)	(0)	(0)
Profit After Tax (norm)	(15,587)	(13,366)	(13,593)	(15,491)
Profit After Tax (FRS 3)	(15,419)	(13,368)	(13,593)	(15,491)
Average Number of Shares Outstanding (m)	1.6	8.0	17.1	17.2
EPS - normalised ($)	(9.81)	(1.68)	(0.80)	(0.90)
EPS - Reported ($)	(9.80)	(1.68)	(0.80)	(0.90)
Dividend per share ($)	0.0	0.0	0.0	0.0
BALANCE SHEET				
Fixed Assets	3,118	3,167	3,149	3,137
Intangible Assets	1,954	1,686	1,540	1,394
Tangible Assets	836	1,222	1,350	1,484
Other	329	259	259	259
Current Assets	3,190	5,490	2,995	6,234
Stocks	533	544	544	544
Debtors	810	374	241	423
Cash	1,847	4,572	2,211	5,267
Other	0	0	0	0
Current Liabilities	(2,882)	(2,438)	(2,039)	(2,039)
Creditors	(1,871)	(2,039)	(2,039)	(2,039)
Short term borrowings	(1,011)	(399)	0	0
Long Term Liabilities	(429)	(1,260)	(6,304)	(23,519)
Long term borrowings	0	(660)	(5,660)	(22,827)
Other long term liabilities	(429)	(600)	(644)	(692)
Net Assets	2,997	4,960	(2,198)	(16,187)
CASH FLOW				
Operating Cash Flow	(14,304)	(11,074)	(11,788)	(13,962)
Net Interest	0	0	0	0
Tax	0	0	0	0
Capex	(277)	(137)	(143)	(149)
Acquisitions/disposals	0	0	0	0
Financing	12,640	14,128	5,022	0
Dividends	0	0	0	0
Other	(205)	(293)	(399)	0
Net Cash Flow	(2,146)	2,624	(7,308)	(14,110)
Opening net debt/(cash)	(3,094)	(836)	(3,514)	3,450
HP finance leases initiated	0	0	0	0
Exchange rate movements	0	0	0	0
Other	(112)	54	345	0
Closing net debt/(cash)	(836)	(3,514)	3,450	17,560

Source: Edison Investment Research, company reports

Contact details	Revenue by geography
708 Quince Orchard Road Gaiterhsburg, MD 20878 US +1-301-869-9683 www.opgen.com	

Management team

Chairman and CEO: Evan Jones	CFO: Timothy Dec
Mr Jones is the chairman and CEO of OpGen and the managing member of jVen Capital, a life sciences investment company. Prior to forming jVen Capital, he was co-founder, chairman and CEO of Digene Corporation, a publicly traded biotechnology company focused on women's health and molecular diagnostic testing. He was a board member of Fluidigm and Foundation Medicine, and is currently a board member at Veracyte. Mr Jones is vice chairman of the Board of the Children's National Medical Center and a board member of the Children's Research Institute.	Mr Dec has more than 20 years of public company financial leadership experience in the technology and healthcare sector. He has served in CFO and other senior financial executive roles at companies in a number of industries, including three publicly traded companies listed on Nasdaq or AMEX, such as Corvis Corporation, and at private equity-backed companies. From August 2007 to December 2012, he was senior VP and CFO of Fortress International Group, a publicly traded company.
Chief Information Officer: Vadim Sapiro	**Senior Vice President, Research and Development: Terry Walker**
Mr Sapiro joined OpGen in December 2011, with responsibility for leading the development of its bioinformatics applications, software, databases and information technology operations. Prior to OpGen, he was senior VP at SAIC-Frederick, overseeing the information systems program for the National Cancer Institute at Frederick with responsibility for information technology, scientific computing and bioinformatics. Previously, Mr Sapiro was VP for information technology with the J Craig Venter Institute. He is active in the regional and national technology and research communities, having served on many life sciences and biotech-focused advisory boards and review committees.	Dr Walker's responsibilities include leading the development of genomic technologies and new products supporting molecular diagnostics for infectious diseases. Prior to OpGen, he led drug target validation, biomarker discovery and clinical diagnostic development at Pfizer, GlaxoSmithKline (GSK), Becton Dickinson (BD), Duke University and The Biomarker Factory across most disease areas and stages of development from discovery through late clinical trials. Dr Walker received his PhD in biophysical chemistry from the University of Rochester with postdoctoral training in biophysical chemistry at the University of California, Berkeley.

Principal shareholders	(%)
Merck Global Health Innovation Fund	5.60%
Evan Jones	4.65%
Sabby Capital	2.90%
Versant Venture Management	1.18%

Companies named in this report

Merck (MRK), BioMerieux (BIM:FP), Thermo Fisher (TMO), Becton Dickinson (BDX), Bruker (BRKR), Danaher (DHR), Accelerate Diagnostics (AXDX), Curetis (CURE), GenMark Diagnostics (GNMK), Luminex (LMNX), T2 Biosystems (TTOO), Qiagen (QGEN)

General disclaimer and copyright

This report has been commissioned by OpGen and prepared and issued by Edison, in consideration of a fee payable by OpGen. Edison Investment Research standard fees are £49,500 pa for the production and broad dissemination of a detailed note (Outlook) following by regular (typically quarterly) update notes. Fees are paid upfront in cash without recourse. Edison may seek additional fees for the provision of roadshows and related IR services for the client but does not get remunerated for any investment banking services. We never take payment in stock, options or warrants for any of our services.

Accuracy of content: All information used in the publication of this report has been compiled from publicly available sources that are believed to be reliable, however we do not guarantee the accuracy or completeness of this report and have not sought for this information to be independently verified. Opinions contained in this report represent those of the Edison analyst at the time of publication. Forward-looking information or statements in this report contain information that is based on assumptions, forecasts of future results, estimates of amounts not yet determinable, and therefore involve known and unknown risks, uncertainties and other factors which may cause the actual results, performance or achievements of their subject matter to be materially different from current expectations.

Exclusion of Liability: To the fullest extent allowed by law, Edison shall not be liable for any direct, indirect or consequential losses, loss of profits, damages, costs or expenses incurred or suffered by you arising out or in connection with the access to, use of or reliance on any information contained on this note.

No personalised advice: The information that we provide should not be construed in any manner whatsoever as, personalised advice. Also, the information provided by us should not be construed by any subscriber or prospective subscriber as Edison's solicitation to effect, or attempt to effect, any transaction in a security. The securities described in the report may not be eligible for sale in all jurisdictions or to certain categories of investors.

Investment in securities mentioned: Edison has a restrictive policy relating to personal dealing and conflicts of interest. Edison Group does not conduct any investment business and, accordingly, does not itself hold any positions in the securities mentioned in this report. However, the respective directors, officers, employees and contractors of Edison may have a position in any or related securities mentioned in this report, subject to Edison's policies on personal dealing and conflicts of interest.

Australia

Edison Investment Research Pty Ltd (Edison AU) is the Australian subsidiary of Edison. Edison AU is a Corporate Authorised Representative (1252501) of Myonlineadvisers Pty Ltd who holds an Australian Financial Services Licence (Number: 427484). This research is issued in Australia by Edison AU and any access to it, is intended only for "wholesale clients" within the meaning of the Corporations Act 2001 of Australia. Any advice given by Edison AU is general advice only and does not take into account your personal circumstances, needs or objectives. You should, before acting on this advice, consider the appropriateness of the advice, having regard to your objectives, financial situation and needs. If our advice relates to the acquisition, or possible acquisition, of a particular financial product you should read any relevant Product Disclosure Statement or like instrument.

New Zealand

The research in this document is intended for New Zealand resident professional financial advisers or brokers (for use in their roles as financial advisers or brokers) and habitual investors who are "wholesale clients" for the purpose of the Financial Advisers Act 2008 (FAA) (as described in sections 5(c) (1)(a), (b) and (c) of the FAA). This is not a solicitation or inducement to buy, sell, subscribe, or underwrite any securities mentioned or in the topic of this document. For the purpose of the FAA, the content of this report is of a general nature, is intended as a source of general information only and is not intended to constitute a recommendation or opinion in relation to acquiring or disposing (including refraining from acquiring or disposing) of securities. The distribution of this document is not a "personalised service" and, to the extent that it contains any financial advice, is intended only as a "class service" provided by Edison within the meaning of the FAA (i.e. without taking into account the particular financial situation or goals of any person). As such, it should not be relied upon in making an investment decision.

United Kingdom

Neither this document and associated email (together, the "Communication") constitutes or form part of any offer for sale or subscription of, or solicitation of any offer to buy or subscribe for, any securities, nor shall it or any part of it form the basis of, or be relied on in connection with, any contract or commitment whatsoever. Any decision to purchase shares in the Company in the proposed placing should be made solely on the basis of the information to be contained in the admission document to be published in connection therewith.

This Communication is being distributed in the United Kingdom and is directed only at (i) persons having professional experience in matters relating to investments, i.e. investment professionals within the meaning of Article 19(5) of the Financial Services and Markets Act 2000 (Financial Promotion) Order 2005, as amended (the "FPO") (ii) high net-worth companies, unincorporated associations or other bodies within the meaning of Article 49 of the FPO and (iii) persons to whom it is otherwise lawful to distribute it. The investment or investment activity to which this document relates is available only to such persons. It is not intended that this document be distributed or passed on, directly or indirectly, to any other class of persons and in any event and under no circumstances should persons of any other description rely on or act upon the contents of this document (nor will such persons be able to purchase shares in the placing).

This Communication is being supplied to you solely for your information and may not be reproduced by, further distributed to or published in whole or in part by, any other person.

United States

The Investment Research is a publication distributed in the United States by Edison Investment Research, Inc. Edison Investment Research, Inc. is registered as an investment adviser with the Securities and Exchange Commission. Edison relies upon the "publishers' exclusion" from the definition of investment adviser under Section 202(a) (11) of the Investment Advisers Act of 1940 and corresponding state securities laws. This report is a bona fide publication of general and regular circulation offering impersonal investment-related advice, not tailored to a specific investment portfolio or the needs of current and/or prospective subscribers. As such, Edison does not offer or provide personal advice and the research provided is for informational purposes only. No mention of a particular security in this report constitutes a recommendation to buy, sell or hold that or any security, or that any particular security, portfolio of securities, transaction or investment strategy is suitable for any specific person.

Frankfurt +49 (0)69 78 8076 960
Schumannstrasse 34b
60325 Frankfurt
Germany

London +44 (0)20 3077 5700
280 High Holborn
London, WC1V 7EE
United Kingdom

New York +1 646 653 7026
1,185 Avenue of the Americas
3rd Floor, New York, NY 10036
United States of America

Sydney +61 (0)2 8249 8342
Level 4, Office 1205
95 Pitt Street, Sydney
NSW 2000, Australia