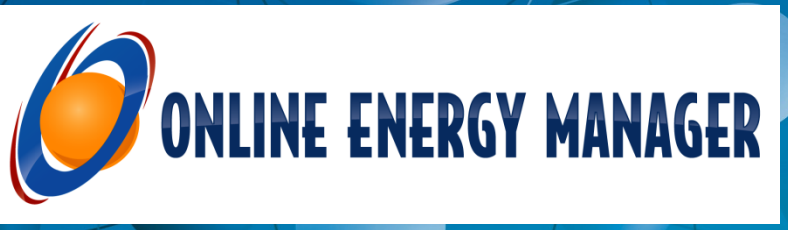
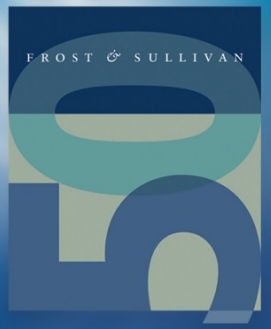
IP & Business Model Valuation and Competitive Tech-IP Due-diligence

Tech Area: Energy Management Controller



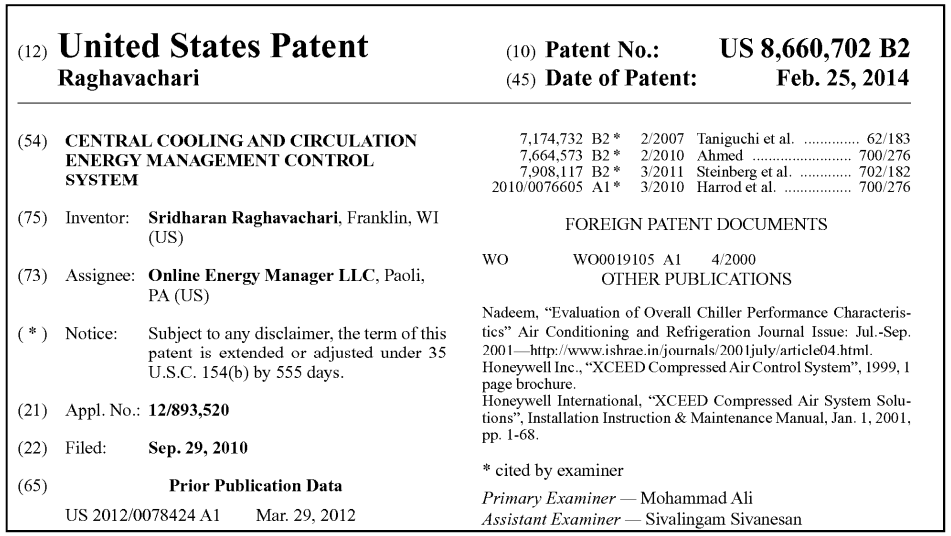


Final Report (Version 5) submitted to: Online Energy Manager

June 30th, 2017

Contents

Summary of Project Objectives



(12) **United States Patent**
Raghavachari

(10) **Patent No.: US 8,660,702 B2**
(45) **Date of Patent: Feb. 25, 2014**

(54) **CENTRAL COOLING AND CIRCULATION ENERGY MANAGEMENT CONTROL SYSTEM**

(75) Inventor: **Sridharan Raghavachari**, Franklin, WI (US)

(73) Assignee: **Online Energy Manager LLC**, Paoli, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 555 days.

(21) Appl. No.: **12/893,520**

(22) Filed: **Sep. 29, 2010**

(65) **Prior Publication Data**

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* cited by examiner

Primary Examiner — Mohammad Ali
Assistant Examiner — Sivalingam Sivanesan

WS 3

IP VALUATION AND BUSINESS MODEL VALUATION

IP AND TECHNOLOGY DUE DILIGNECE

Patent Landscape overview and competitive assessment from Tech-IP perspective

Market Assessment

Valuation IP Aseets (Patent + Know-how) and Business Model

WS 1

WS 2

Valuation Philosophy: Tech-IP + Business Model Valuation

Business Model Valuation

Based on amount of cash flow generated by adopting various Business Contract Models specific to Energy Efficiency improvement

Technology / IP Valuation

Based on royalty based cash flow that an asset is expected to generate over its useful life.

Scenario-wise Addressable Market

Royalties based Cash Flow

Total Risk Adjusted Net Present Value (rNPV)

Global Chiller Equipment Market

Chiller Equipment – Market Engineering Measurements

Chiller Equipment Segment: Market Engineering Measurements, Global, 2014

Measurement Name	Measurement	Trend
Segment stage	Mature	-
Segment revenue (2014)	$16.77 B	▲
Segment forecast (2020)	$22.96 B	▲
Base year segment growth rate	5.3%	●
Compound annual growth rate (CAGR, 2014–2020)	5.4%	-
Price sensitivity (scale of 1 to 10, low to high)	9	▲
Number of competitors (active market competitors in base year)	50+	●
Degree of competition (scale of 1 to 10, low to high)	8	▲
Degree of technical change (scale of 1 to 10, low to high)	6	▲
Customer loyalty (scale of 1 to 10, low to high)	7	●
Segment concentration (base year market share controlled by top 4 competitors)	80.4%	●

Decreasing ▼ Stable ● Increasing ▲

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Chiller Equipment Segment Overview

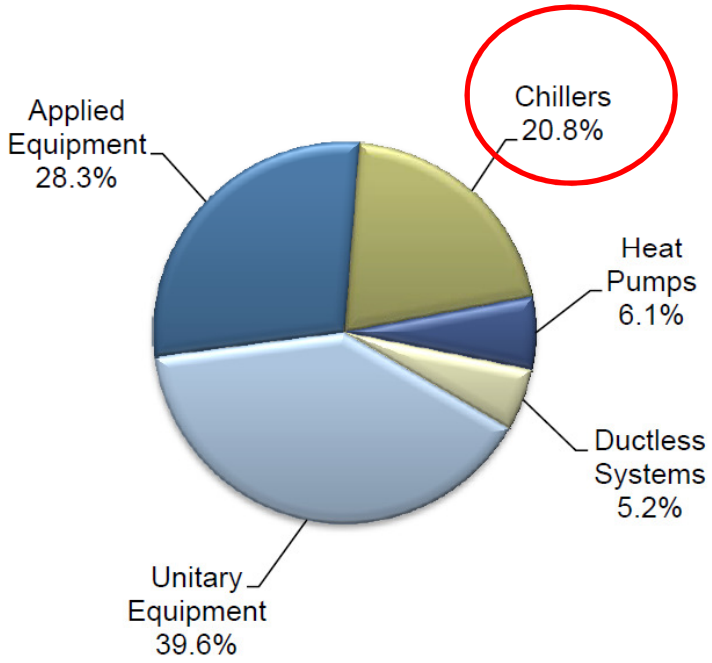
Key Takeaway: Increased demand for high-performance chiller systems will drive revenue growth.

Important Segment Characteristics

Factors	Assessment	Trend
Opportunity size ($ M)*	The chiller equipment segment is anticipated to grow steadily, reaching $22.96 billion by 2020	▲
Primary needs	High energy efficiency and low price	●
Price sensitivity	Price sensitivity is very high in the chiller system market	▲
Purchase Influencers	Price, efficiency, and timely delivery	●
Distribution structure	Manufacturer reps, distributers/contractors, and direct partners	●
Demand for innovation	Medium	●

Decreasing ▼ Stable ● Increasing ▲

Total HVAC Equipment Market: Percent Revenue by Segment, Global, 2014



Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Chiller Equipment - Revenue Forecast Discussion

- In 2014, the total chiller equipment market was $16.77 billion growing at a CAGR of 5.4%. The market is expected to grow through 2020 and reach $22.96 billion.
- The main driver for this market will be the need for energy-efficient chillers that offer energy savings and retrofit applications. Another driver is the increasing demand for air-cooled chillers because they can operate without a cooling tower and require less maintenance.
- Revival of the construction industry and replacement activities have encouraged the installation of chillers across all verticals.
- Increased spending on primary and secondary school construction has provided higher growth for the institutional chiller market.
- The demand for chillers has also increased in the data center applications. The heat generated in an IT storage room can be easily reduced with air-cooled chillers. The market is also experiencing a shift from water-cooled systems to air-cooled systems.
- With changes in the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standards 90.1, analysis indicates that the global chiller market is experiencing a shift to more efficient and reliable chillers.
- Tier I companies control the maximum share in the chiller equipment market. The market indicates acquisition activities, and companies are expanding their customer base and distribution channel.
- According to the key industry participants, the manufacturing base in the APAC regions is much wider than in North America. Most of the products are entering the NA market from APAC. It is much cheaper for companies to get the systems shipped from the APAC regions.

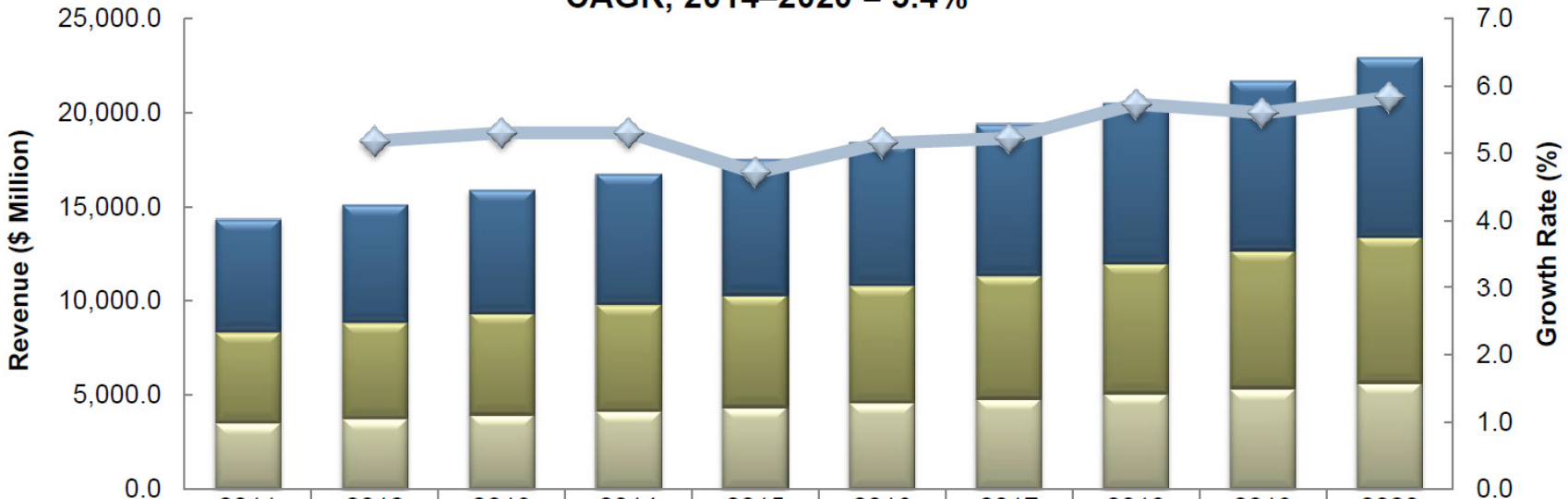
Source: American Society of Heating, Refrigerating, and Air-Conditioning Engineers(ASHRAE); Frost & Sullivan

Chiller Equipment Revenue Forecast by Vertical Market

Key Takeaway: Demand for efficient and reliable systems in the commercial sector will drive demand for chiller systems.

Chiller Equipment Segment: Revenue Forecast by Vertical Market, Global, 2011–2020

CAGR, 2014–2020 = 5.4%



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Commercial	6,008.9	6,259.9	6,592.0	6,930.4	7,251.6	7,625.2	8,043.1	8,504.2	8,980.4	9,527.0
Industrial	4,844.5	5,095.6	5,365.9	5,675.0	5,952.3	6,240.5	6,586.0	6,963.6	7,353.6	7,782.3
Institutional	3,522.0	3,765.0	3,964.7	4,162.0	4,354.5	4,597.3	4,798.6	5,073.8	5,357.9	5,647.3
Growth Rate	-	5.2	5.3	5.3	4.7	5.2	5.2	5.7	5.6	5.8

Year

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Chiller Equipment Revenue Forecast Discussion by Vertical Market

- The largest vertical was the commercial market accounting for 41.3% of the total chiller equipment market in 2014.
- Recovered economy and the increased demand from offices, retail chains, and airports since 2013 have increased new installations and replacements of large tonnage chillers in commercial markets.
- The demand for cooling in data centers is also creating demand for chillers. The air-cooled chillers and outside economizers are in great demand for IT applications. These segments are taking away share from the water-cooled systems.
- The second-largest vertical in the chillers market was the industrial market, with a revenue share of 33.8% in 2014.
- The demand for absorption chillers offers increased reliability and enhanced performance in the industrial sector. However, the air-cooled systems still dominate the commercial market. The systems are highly scalable for data center infrastructure.
- The third-largest vertical was the institutional market accounting for 24.8% in 2014. Growth in this vertical is expected to be sustained by an increase in healthcare and school construction and renovations.

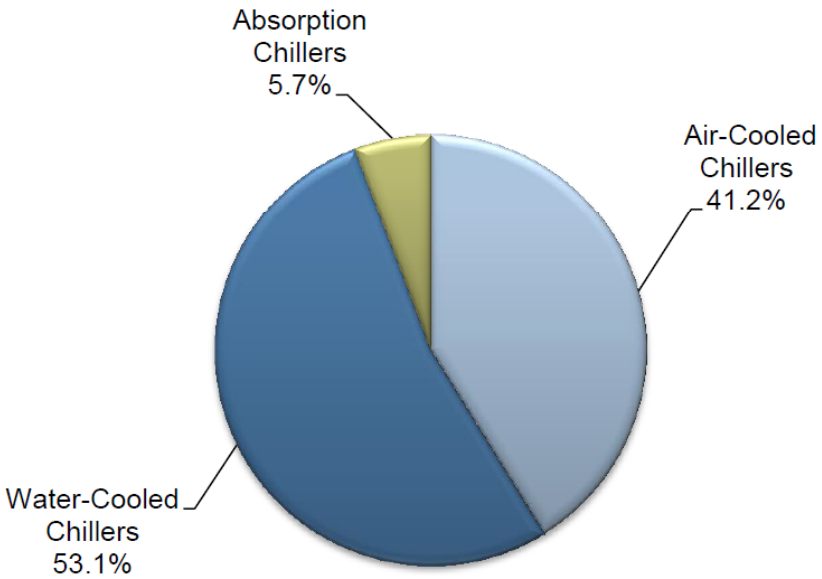
Source: Frost & Sullivan

Chiller Equipment Percent Revenue by Product Type

Key Takeaway: Air-cooled systems are anticipated to present the greatest growth opportunities globally.

- Globally, the water-cooled market is the largest market within the total chiller equipment market. The air-cooled market is taking away share from the water-cooled market, however, because they operate without a cooling tower and/or condenser pumps.
- Nonetheless, air-cooled systems are growing at a faster rate than the rest of the chillers.
- Data center infrastructure is driving the growth for air-cooled systems over water-cooled systems due to mission-critical requirements of the centers.
- The new trends in the market depict that the improved acoustics in the systems keep noise levels down along with integrated temperature control that keeps the chillers reliable.
- Absorption chillers are anticipated to grow over the forecast period. The use of gas-based cooling is a main driver; however, the high initial cost of absorption chillers over some of other conventional compression chillers can pose a hindrance to this product segment.

Chiller Equipment Segment: Percent Revenue by Product Type, Global, 2014

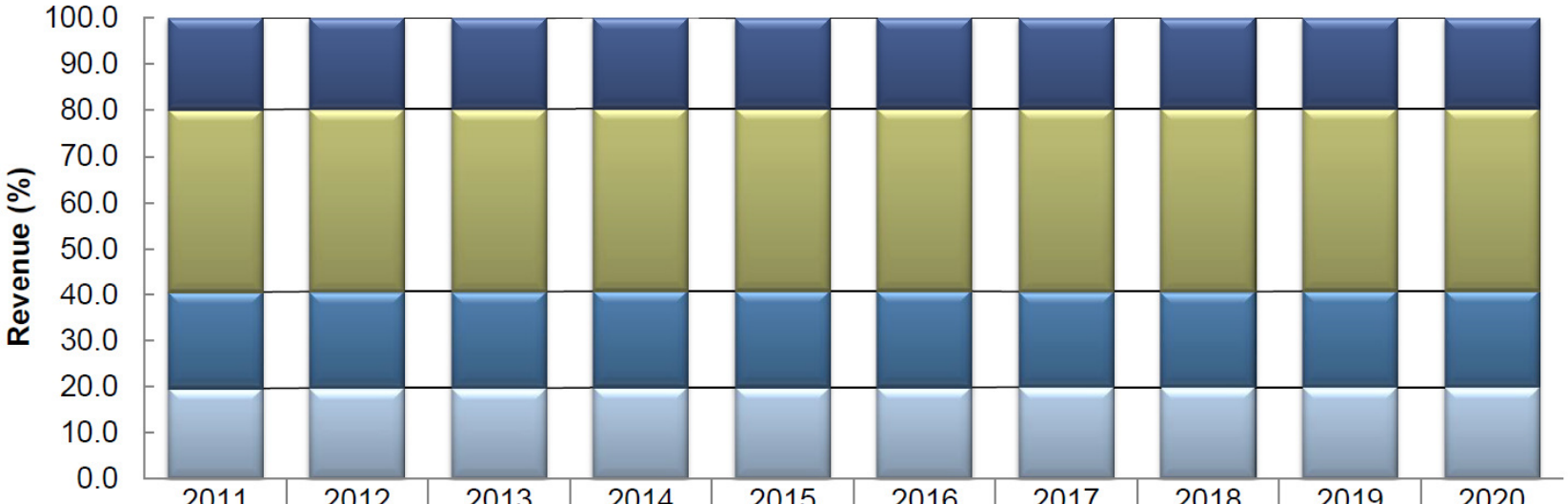


Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Chiller Equipment Percent Revenue Forecast by Region

Key Takeaway: APAC is the key engine for market revenue growth in the chiller equipment market.

Chiller Equipment Segment: Percent Revenue Forecast by Region, Global, 2011–2020



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
ROW	19.8	19.7	19.7	19.7	19.6	19.6	19.6	19.6	19.6	19.6
APAC	39.7	39.7	39.7	39.7	39.7	39.7	39.8	39.8	39.7	39.7
Europe	20.9	20.9	20.9	20.9	20.9	20.9	20.7	20.7	20.8	20.8
North America	19.6	19.7	19.7	19.8	19.8	19.8	19.9	19.9	19.9	19.9

Year

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Chiller Equipment Percent Revenue Forecast by Region

Chiller Equipment Segment: Revenue Forecast by Region, Global, 2011–2020

Year	North America ($ Million)	Europe ($ Million)	APAC ($ Million)	ROW ($ Million)
2011	2,817.6	3,004.4	5,707.0	2,846.3
2012	2,978.8	3,160.2	6,002.9	2,978.8
2013	3,136.8	3,327.8	6,321.3	3,136.8
2014	3,312.0	3,503.5	6,651.8	3,300.1
2015	3,476.5	3,669.7	6,970.6	3,441.4
2016	3,655.7	3,858.8	7,329.8	3,618.7
2017	3,866.1	4,021.5	7,732.2	3,807.8
2018	4,087.8	4,252.1	8,175.5	4,026.1
2019	4,316.7	4,511.9	8,611.7	4,251.6
2020	4,568.3	4,775.0	9,113.7	4,499.5
CAGR (%)	**5.5**	**5.3**	**5.4**	**5.3**

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Chiller Equipment Percent Revenue Forecast by Region Discussion

Asia-Pacific

- The APAC region generated the highest revenue in 2014 accounting for $6,651.8 million revenue and 39.7% of the segment market share. An industry trend across the APAC region requires commercial, industrial, and institutional verticals to deploy energy-efficient chillers.
- The main driver for this market will be the need for energy-efficient chillers that offer energy savings and retrofit applications. The APAC regions promise a big market for absorption chillers.
- The high initial cost of absorption chillers over some of other conventional compression chillers is one of the major market restraints.

Europe

- The European market is rapidly changing with respect to technological innovation which offers improved models in terms of technical specifications.
- In 2014, the European market contributed $3,503.5 in revenue to the total global chiller equipment market. The market will continue to grow at a CAGR of 5.3%; however, the slow economy and intense competition among the established vendors will pose fundamental challenges.
- After the euro crisis, recovery has been study in the European construction industry, which is driving sales in the commercial and industrial sectors.

Source: Natural Resource Canada, Frost & Sullivan

Chiller Equipment Percent Revenue Forecast by Region Discussion

North America

- In North America, chillers currently contribute 19.8% of the total global chiller equipment market.
- Companies are increasingly focusing on controlling energy consumption and are replacing older equipment.
- Changes in the technology based on smart solutions have driven the market towards chillers with better dependability, electricity savings, lower maintenance, and operational costs.

Rest of World

- ROW accounted for 19.7% of the total global chiller market in 2014. The market is largely driven by construction and retrofit activities, government regulations, and attaining the highest level of energy efficiency.
- Comfort cooling and precision cooling are evolving in the commercial segment across India. Due to the scalability and reliability of chillers, they have captured market share throughout this country.
- The Middle East shows positive growth opportunities for absorption chillers. The Middle East is heavily climate controlled, and demand for air conditioning is rising, putting increasing pressure on electricity supplies. These factors will help the Middle East slowly gain traction in the chiller equipment market over the forecast period.

Source: Natural Resource Canada, Frost & Sullivan

Chiller Equipment Market Share Analysis

The top 4 chiller equipment participants contributed 80.4% of total market revenue.

Daikin Global leads the chiller segment with its extensive product portfolio for chillers. Its new, innovative air-cooled systems are designed to help manage energy costs across all verticals, particularly within institutional and commercial buildings.

Carrier (UTC) followed with 20.3% share of that total chiller market. Its extensive product offering and established distribution channel has helped to consolidate its position.

Following Carrier (UTC) in market ranking is JCI York with 19. 6% market share. JCI's collaboration with York has strengthened its portfolio. Additionally, its chiller product line depicts low life cycle cost, meets or exceeds ASHRAE standards, and reduces noise levels.

Trane followed in the fourth position with 18.8% of total market revenues in 2014.

Their global presence, extensive product portfolios, and established distribution networks position these participants to remain the market leaders.

Chiller Equipment Segment: Company Market Share Analysis of Top 4 Participants, Global, 2014

Company	Revenue ($ Billion)
Daikin Global	3.61
Carrier (UTC)	3.40
JCI York	3.28
Trane	3.16
*Others	3.32
Total	**16.77**

*Others include Dunham-Bush, Nortek Global solutions, AAON Inc., Lennox International, Rheem Mfg. Co.
Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Global HVAC Controls Market

(OEM technology applies to the energy efficiency segment of the market)

Definition of HVAC Controls Market

- The purpose of an HVAC control system is to regulate and manage the flow of air, water, or steam in order to stabilize operations and desired temperature, humidity, and pressure. The key function of control systems is to monitor and control energy consumption of the equipment, respond to events, and enhance operational efficiency of the equipment.
- The HVAC control systems are required in all applications to provide an acceptable level of occupancy comfort and minimize energy requirements and costs.
- HVAC control systems are a combination of computerized and microprocessor-based control and monitoring products, installed as a single system. The systems are composed of a central user interface, communication network, and data acquisition/direct digital controllers.
- The control process involves a sensor, controller, output signal, and an end device. The sensor provides the input to the controller by converting physical elements such as temperature, pressure, and humidity into an electronic signal that is read by the controller.
- The controller reads the electronic signal from the sensor, applies programmed logic, and provides output to the end device.
- In this research service the HVAC control systems are segmented by the following product and technologies:
  - Stand-alone HVAC control systems
  - Programmable HVAC control systems
  - Thermostats

Source: Frost & Sullivan

Definition of HVAC Controls Market (Continued)

Segmentation definitions by product are as follows:

- **Stand-alone HVAC Controls Systems:** These controls are used for systems that are stand-alone or operate sufficiently without being integrated into broader systems. They have limited programmable options.
- These are deployed on facilities up to 150,000 square feet in area, single- or two-story buildings.
- They are also referred to as the controllers which are utilized in air handling units (AHUs), fan coils, heat pumps, and other terminal units.
- Only the commercial, residential, and institutional verticals are evaluated under this segment. The residential vertical comprises multi-dwelling apartments and condominiums.

- **Programmable Control Systems:** These control systems can be programmed to integrate several stand-alone systems or protocols necessary for more complex building applications. They are more preferred to stand-alone control systems. They are also called a master global controller.
- They are deployed in facilities of more than 150,000 square feet in area, multi-storey, multi-zone buildings requiring complex functionalities and capabilities.
- They can be programmed per end-user specifications and are utilized in chillers, AHUs and other heating systems.
- Only the commercial, industrial, and institutional verticals are evaluated under this segment.

Source: Frost & Sullivan

Market Drivers

Total HVAC Controls Market: Key Market Drivers, North America, 2016–2022

Drivers	1–2 Years	3–4 Years	5–7 Years
Increased rate of construction and building renovations increase demand for HVAC systems	H	H	H
Increased focus on indoor air quality pushes the market towards the sale of energy-efficient control systems across verticals	H	H	H
Connectivity and interoperability of systems drives demand for HVAC controls	H	H	M
Demand for smart devices fuels future proliferation of advanced HVAC controls	M	M	M
A raft of new regulations will address HVAC systems	M	M	M

Impact Ratings: H = High, M = Medium, L = Low

Source: Frost & Sullivan

Market Restraints

Total HVAC Controls Market: Key Market Restraints, North America, 2016–2022

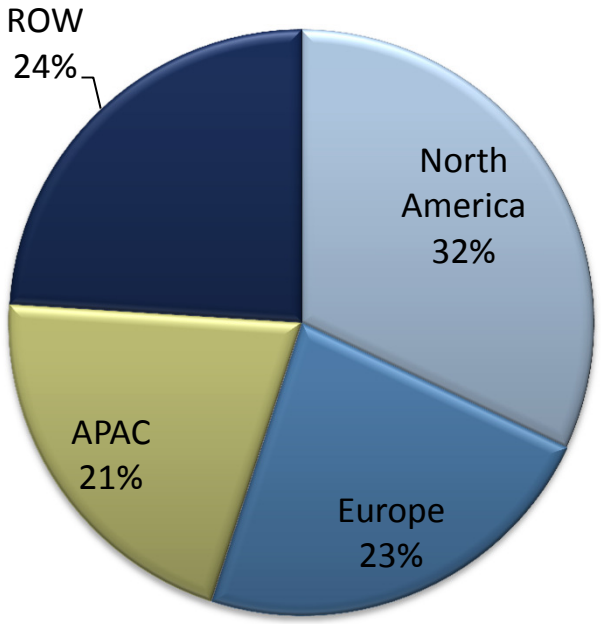
Restraints	1–2 Years	3–4 Years	5–7 Years
Lack of a trained labour pool and a gap in knowledge form a barrier to growth for the HVAC industry	**M**	**M**	**M**
Increasing price competition and competitive bidding reduce market potential	**M**	**M**	**M**
Managing higher initial upfront costs deters adoption	**L**	**L**	**L**

Impact Ratings: H = High, M = Medium, L = Low

Source: Frost & Sullivan

Global Programmable HVAC Controls Segment: Regional Breakdown

Programmable HVAC Controls Segment: Percent Revenue Breakdown, Global, 2015



Region	Revenues ($ Million)	CAGR (%)
North America	4614.2	5.3
Europe	3316.5	4.4
APAC	3028.1	5.6
Rest of the World	3460.7	4.7
Global	14419.38	4.9

Note: All figures are rounded. Source: Frost & Sullivan analysis.

Global Programmable HVAC Controls Market Specific to Chillers Segment

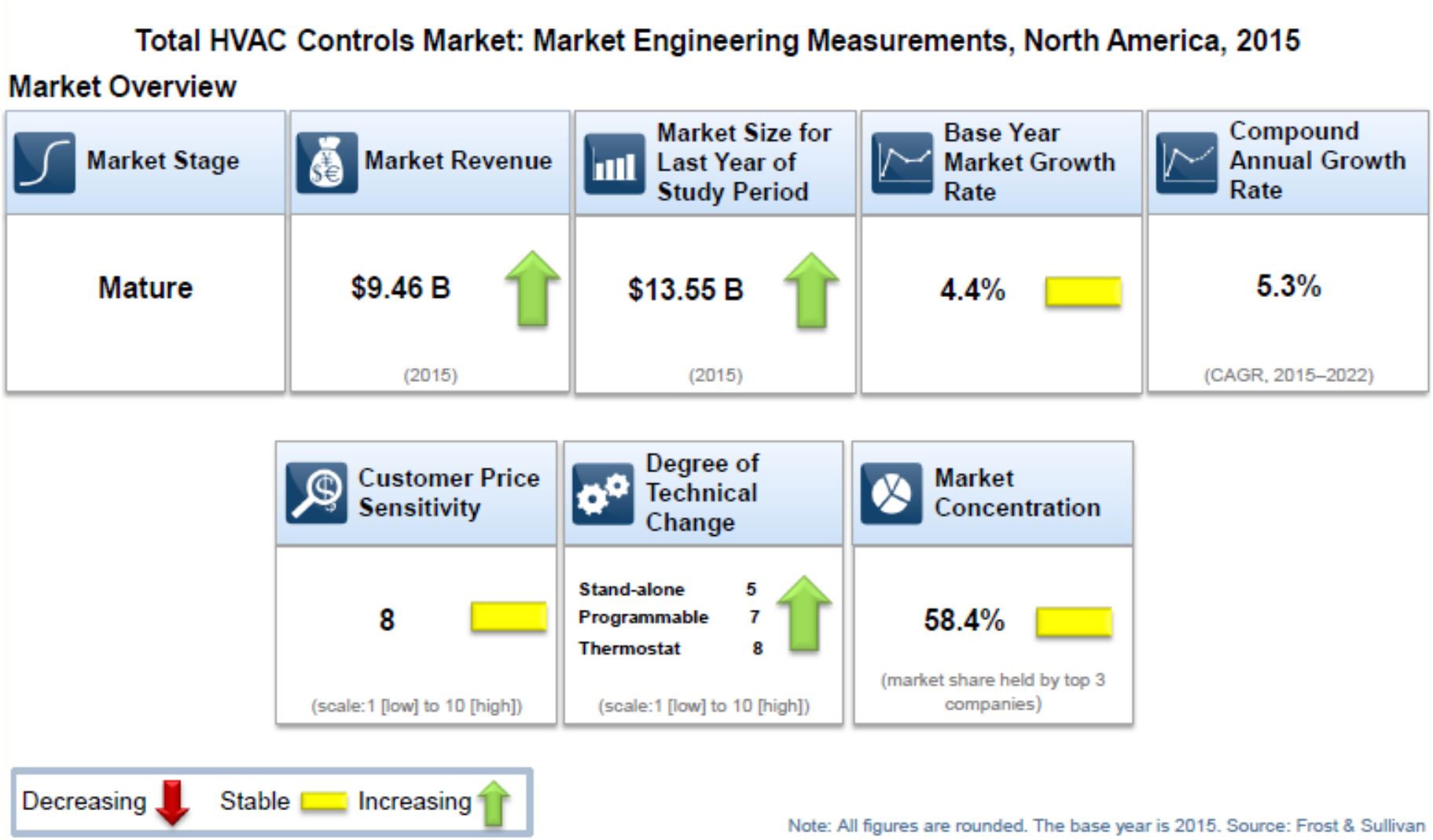
Programmable HVAC Controls For Chillers : Revenue Breakdown, Global, 2015

Region	Revenues ($ Million)	(%) Share of Chillers in Total Market	Revenues for HVAC Controls Specific to Chillers ($ Million)
North America	4614.2	36	1661.1
Europe	3316.5	30	1061.3
APAC	3028.1	22	666.2
Rest of the World	3460.7	38	1315.0
Global	14419.38		4614.2

Note: All figures are rounded. Source: Frost & Sullivan analysis.

North American Programmable HVAC Controls Market

Market Engineering Measurements



Note: All figures are rounded. The base year is 2015. Source: Frost & Sullivan

North American Programmable HVAC Controls Market

Programmable HVAC Controls Segment

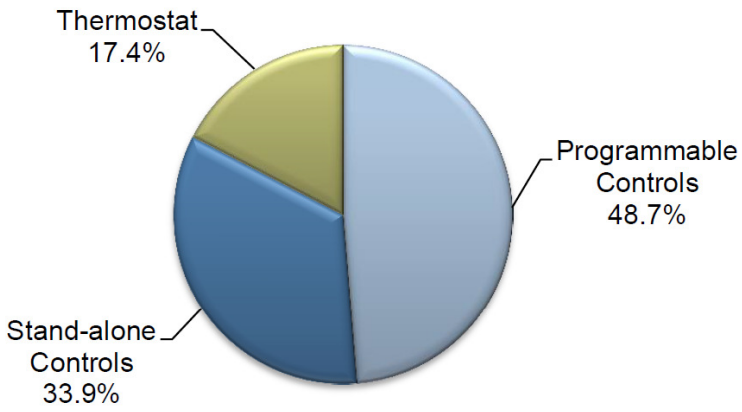
Key Takeaway: This segment has gained a larger share in the market as it can programmed for specific applications, giving end user more flexibility.

Important Segment Characteristics

Factors	Assessment	Trend
Opportunity size	4.61 billion	▲
Primary needs	Complex systems, demand for configuration, use in specific applications	▲
Price sensitivity	High	●
Purchase influencers	Price, brand loyalty, distribution channel, interoperatibilty technology	▲
Distribution structure	Direct sales, distributors, and contractors	●
Demand for innovation	The market indicates stable innovative trends	●

Decreasing ▼ Stable ● Increasing ▲

Total HVAC Controls Market: Percent Revenue Breakdown by Segment, North America, 2015



The opportunity size is comprised of 2015

Note: All figures are rounded. The base year is 2015. Source: Frost & Sullivan

Programmable HVAC Controls – Market Dynamics

Programmable HVAC Controls Segment: Market Engineering Measurements, North America, 2015

Measurement Name	Measurement	Trend
Segment stage	Mature	–
Segment revenue (2015)	$4.61 billion	▲
Segment forecast (2022)	$6.78 billion	▲
Base year segment growth rate	4.6%	●
Compound annual growth rate (CAGR, 2015–2022)	5.6%	–
Price sensitivity (scale of 1 to 10, low to high)	8	●
Number of competitors (active market competitors in base year)	55+	▲
Degree of competition (scale of 1 to 10, low to high)	7	▲
Degree of technical change (scale of 1 to 10, low to high)	7	▲
Customer loyalty (scale of 1 to 10, low to high)	7	●
Segment concentration (base year market share controlled by top 3 competitors)	67.2%	▲

Decreasing ▼ Stable ● Increasing ▲

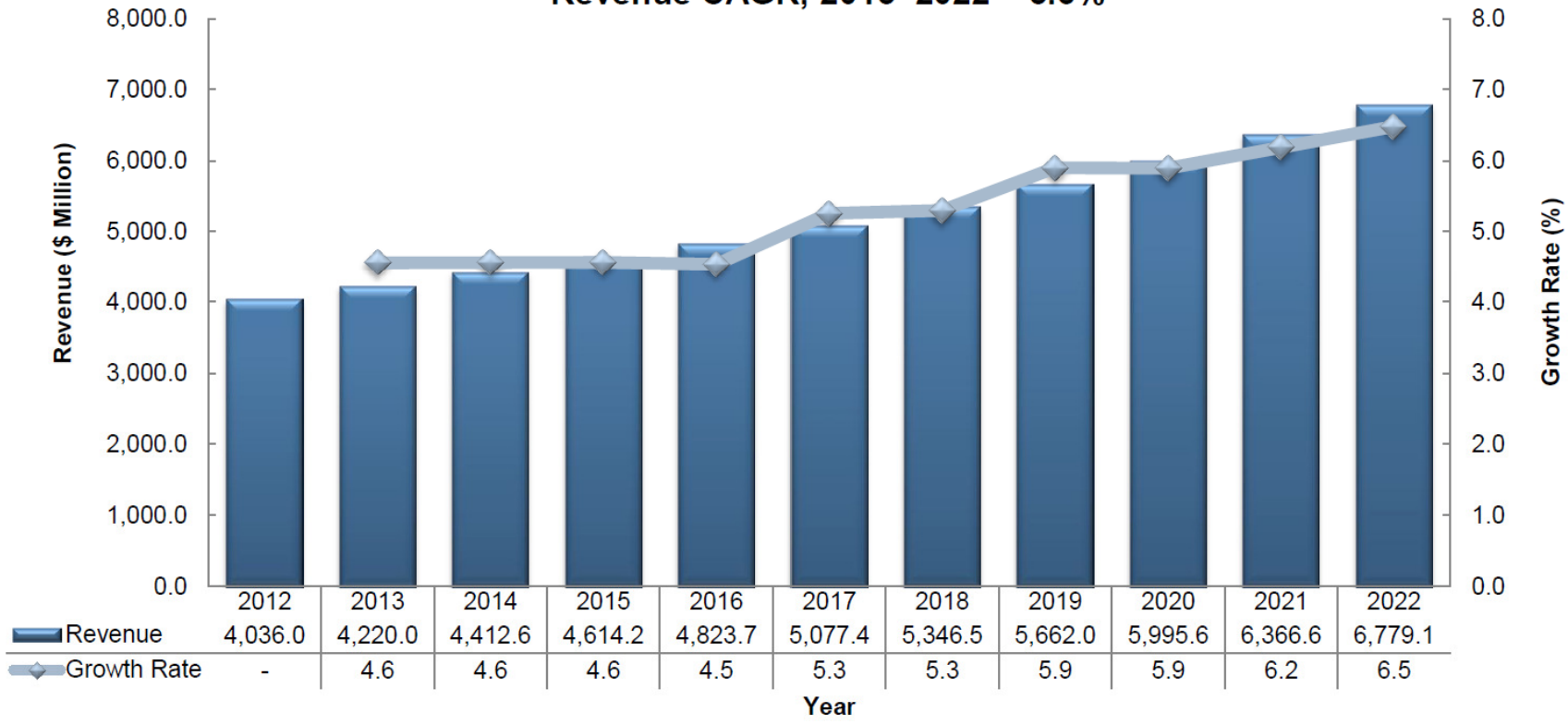
Note: All figures are rounded. The base year is 2015. Source: Frost & Sullivan

Programmable HVAC Controls - Revenue Forecast

Key Takeaway: Revenue growth was fueled by increased use of configurable controls catering to end-users' specifications.

Programmable HVAC Controls Segment: Revenue Forecast, North America, 2012–2022

Revenue CAGR, 2015–2022 = 5.6%



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Revenue	4,036.0	4,220.0	4,412.6	4,614.2	4,823.7	5,077.4	5,346.5	5,662.0	5,995.6	6,366.6	6,779.1
Growth Rate	-	4.6	4.6	4.6	4.5	5.3	5.3	5.9	5.9	6.2	6.5

Year

Note: All figures are rounded. The base year is 2015. Source: Frost & Sullivan

Revenue Forecast Discussion

- The HVAC controls market indicates that the market for the programmable HVAC control segment exceeds that of the stand-alone segment. The programmable market indicates a total revenue of $4.61 billion growing at a CAGR of 5.6% in 2015.
- The main drivers behind the demand for programmable controls are rise in construction of new buildings and structures which leads to increased mechanical and electrical installations of HVAC components. As a result, the market is expected to reach $6.78 billion by 2022.
- In North America building sizes over 150, 000 square feet requiring more complex system controls install the programmable HVAC controls. With advancements in technology and the facilities of this size requiring high-end controls and networking capabilities, communication and interoperability among multiple devices is enabled.
- Additionally, building occupancy is becoming more and more complex. Hence the demand for programmable controls is best suited for applications that require highly functional systems and processes. They are deployed in facilities that demand high-end functionalities and seamless interoperability between devices spread across a large span of square footage.
- Programmable controls are scarcely used in residential applications owing to their smaller size and lesser need for complex capabilities. The residential vertical is not included in this segment.
- Value-added services such as data analytics, remote monitoring, and predictive maintenance along with energy audits are some of the services that the HVAC control manufactures provide to the customers. These services help create lucrative opportunities for the manufactures as well as establish a strong customer base.

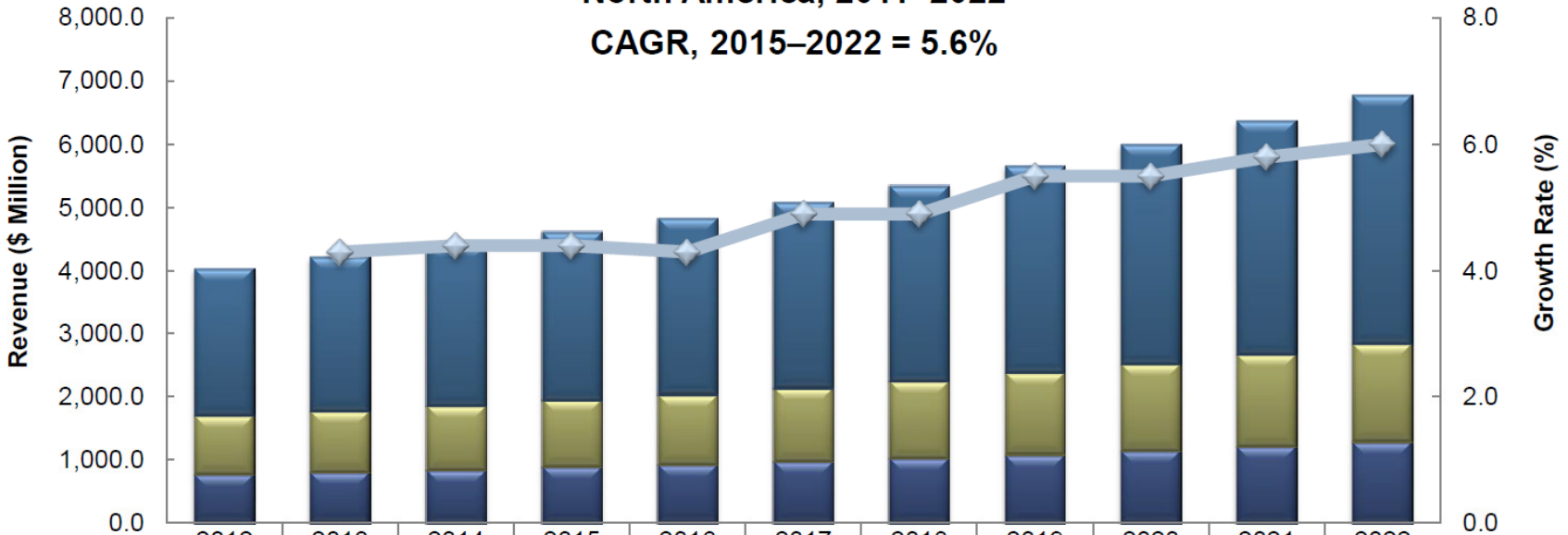
Source: Frost & Sullivan

Revenue Forecast by Vertical Market

Key Takeaway: The commercial and industrial verticals have the greatest growth opportunities for programmable controls due the high-functioning use cases.

Programmable HVAC Controls Segment: Revenue Forecast by Vertical Market, North America, 2011–2022

CAGR, 2015–2022 = 5.6%



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Commercial	2,340.9	2,447.6	2,559.3	2,672.6	2,797.7	2,950.0	3,106.3	3,289.6	3,483.5	3,705.3	3,945.5
Industrial	928.3	970.6	1,014.9	1,058.3	1,104.6	1,162.7	1,224.4	1,296.6	1,373.0	1,457.9	1,552.4
Institutional	766.8	801.8	838.4	883.4	921.3	964.7	1,015.8	1,075.8	1,139.2	1,203.3	1,281.3
Growth Rate	-	4.3	4.4	4.4	4.3	4.9	4.9	5.5	5.5	5.8	6.0

Note: All figures are rounded. The base year is 2015. Source: Frost & Sullivan

Revenue Forecast Discussion by Vertical Market

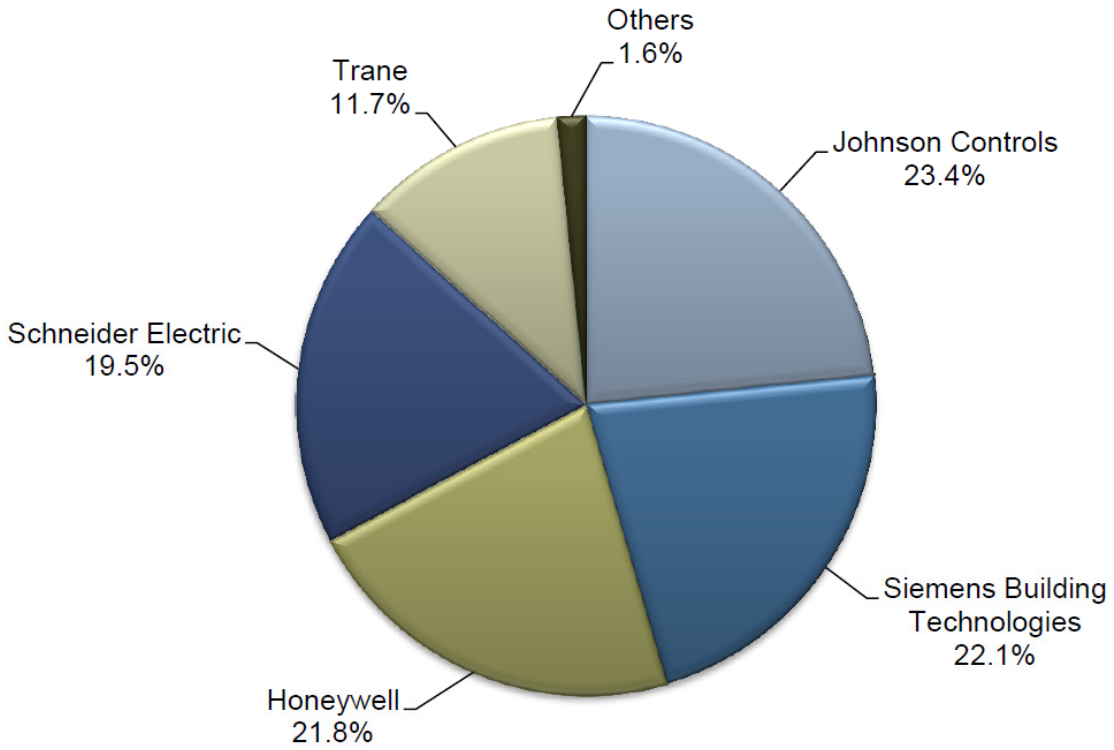
- Vast majority of demand for programmable HVAC control systems is due to new construction. The systems can be easily configured and integrated as per the end-users' requirements and the vertical applications.
- The commercial vertical accounts for the highest revenue of 57.9% of total programmable segment in North America. Analysis indicates that historically, the programmable controls systems did not have the capacity for any additional configured feature. They had limited applications use. Yet current systems have the flexibility to modify and add any software program suitable for a variety of applications.
- The industrial vertical contributes 22.9% of the total programmable market; however, the installation and use of industrial process controls are complex and expensive. These industrial systems usually require very high tolerance, fast control decisions, and smart valve actuators.
- The industrial market is consistently stable and will remain so. The commercial segment will take away market share from the stand-alone systems.
- In the HVAC market chillers and large rooftops are often shipped with controllers so that they can run efficiently and can communicate to monitor the energy efficiency of the compressor. The compressor requires control and hence in the industrial segment, programmable HVAC controls systems have proven to be reliable.
- Educational institutions and facilities generate 19.1% of the total vertical market revenue in North America for programmable HVAC control systems. The increased use of the systems in these facilities help facilities managers to monitor energy controls. This vertical along with the commercial vertical are very attractive revenue generators for manufactures.

Source: Frost & Sullivan

Market Share Analysis

Key Takeaway: A comprehensive suite of products and increased customer loyalty will create dominance of the top companies over the competition.

Programmable HVAC Controls Segment: Percent Revenue Breakdown, North America, 2015



Others include Distec Controls, Delta Controls. KCM Controls, Lennox Int., and other small manufacturers

Note: All figures are rounded. The base year is 2015. Source: Frost & Sullivan

Middle East District Cooling Market

District Cooling Mechanism

District Cooling Mechanism

1. **Central Cooling Plant:**

   Chilled water is distributed from central plant to the customer's building through a network of underground insulated pipes.

2. **Water Circuit:**

   The chilled water is circulated through a water circuit, which is then converted to cool air through a fan coil.

3. **Energy Transfer System:**

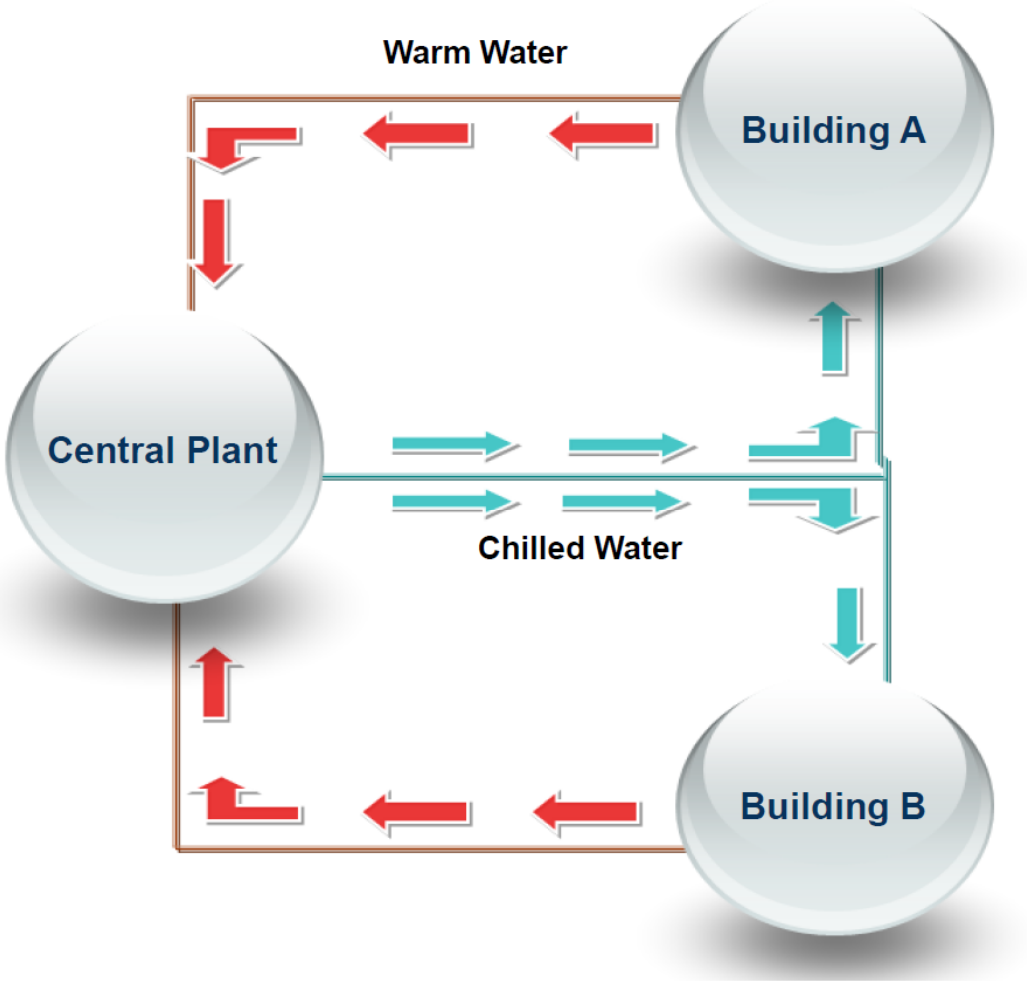
   Cool air is then passed into the energy transfer system.

4. **Cold Water Tube:**

   The air is then forced past the cold water tube to produce a cool environment.

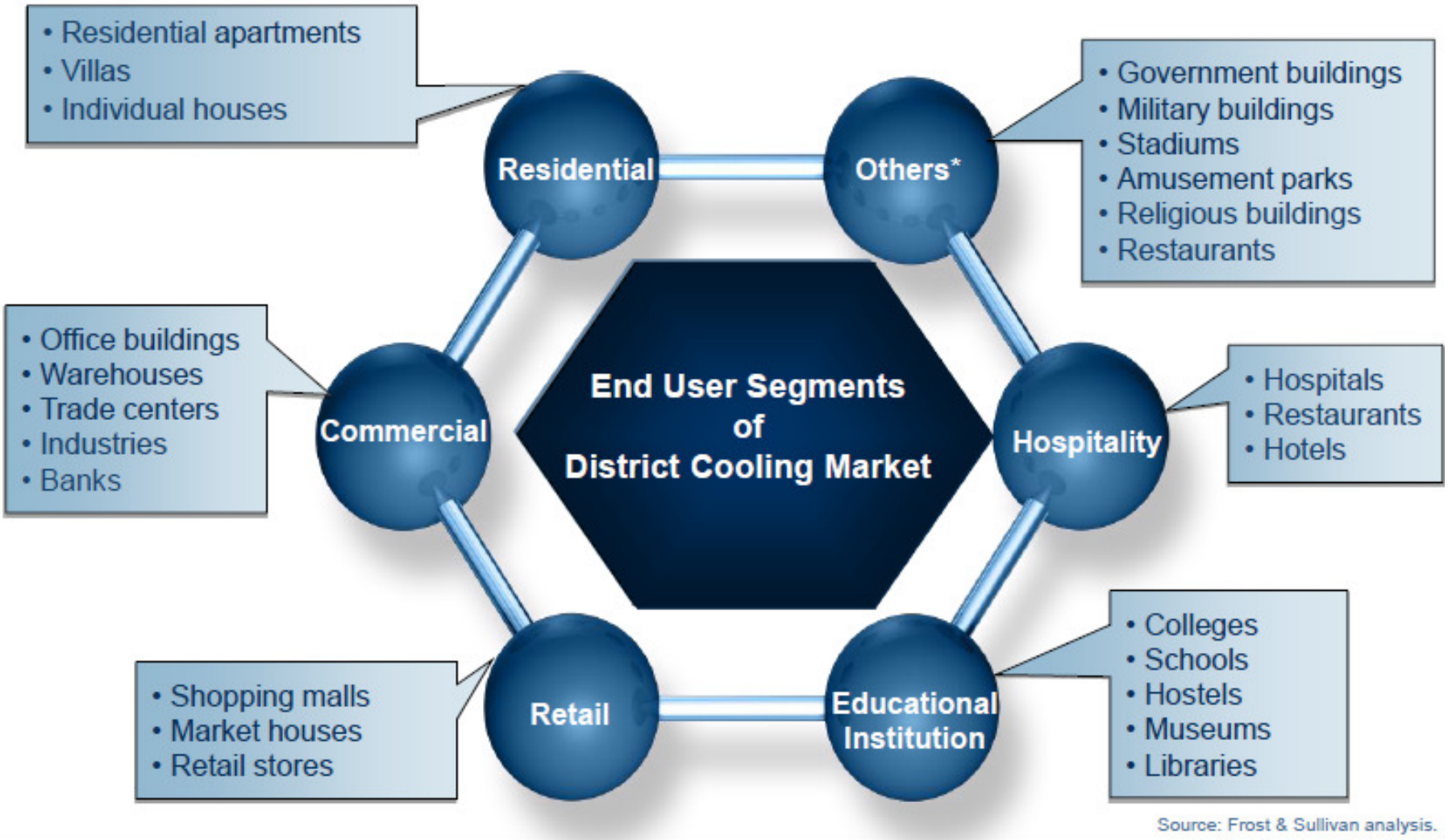
5. **Warm Water:**

   Warm water is then transferred to the central plant to get re-cycled and re-chilled.



Source: Frost & Sullivan analysis.

District Cooling – End User Segments



Source: Frost & Sullivan analysis.

Executive Summary—Market Engineering Measurements

Market Overview
Total District Cooling Market: The Middle East, 2016

Market Stage

Mature

Market Revenues

$2634 M 

(2016)

Market Size at End of Forecast Period

$5881 B 

(2022)

Base Year Market Growth Rate

(15.0%)

Customer Price Sensitivity

9 

(scale:1 [low] to 10 [High])

Degree of Technical Change

5 

(scale:1 [low] to 10 [High])

Decreasing  Stable  Increasing 

Note: All figures are rounded. The base year is 2016. Source: Frost & Sullivan analysis.

Global Data Centre Cooling Market

Data Centre Cooling Market Overview

Total Data Centre Cooling Market: Market Engineering Measurements, Global, 2014

Market Overview

Measurement Name	Measurement	Trend
Market Stage	Mature	—
Market Revenue (2014)	$4,300.0 M	▲
Market Size for Last Year of Study Period (2019)	$6,423.8 M	▲
Base Year Market Growth Rate	7.0%	▲
Compound Annual Growth Rate (CAGR, 2014–2019)	8.4%	—
Customer Price Sensitivity (scale of 1 to 10, Low to High)	7	●
Degree of Technical Change (scale of 1 to 10, Low to High)	7	▲
Market Concentration (% of base year market controlled by top 3 competitors)	69.0%	●

Trend	Decreasing	Stable	Increasing
	▼	●	▲

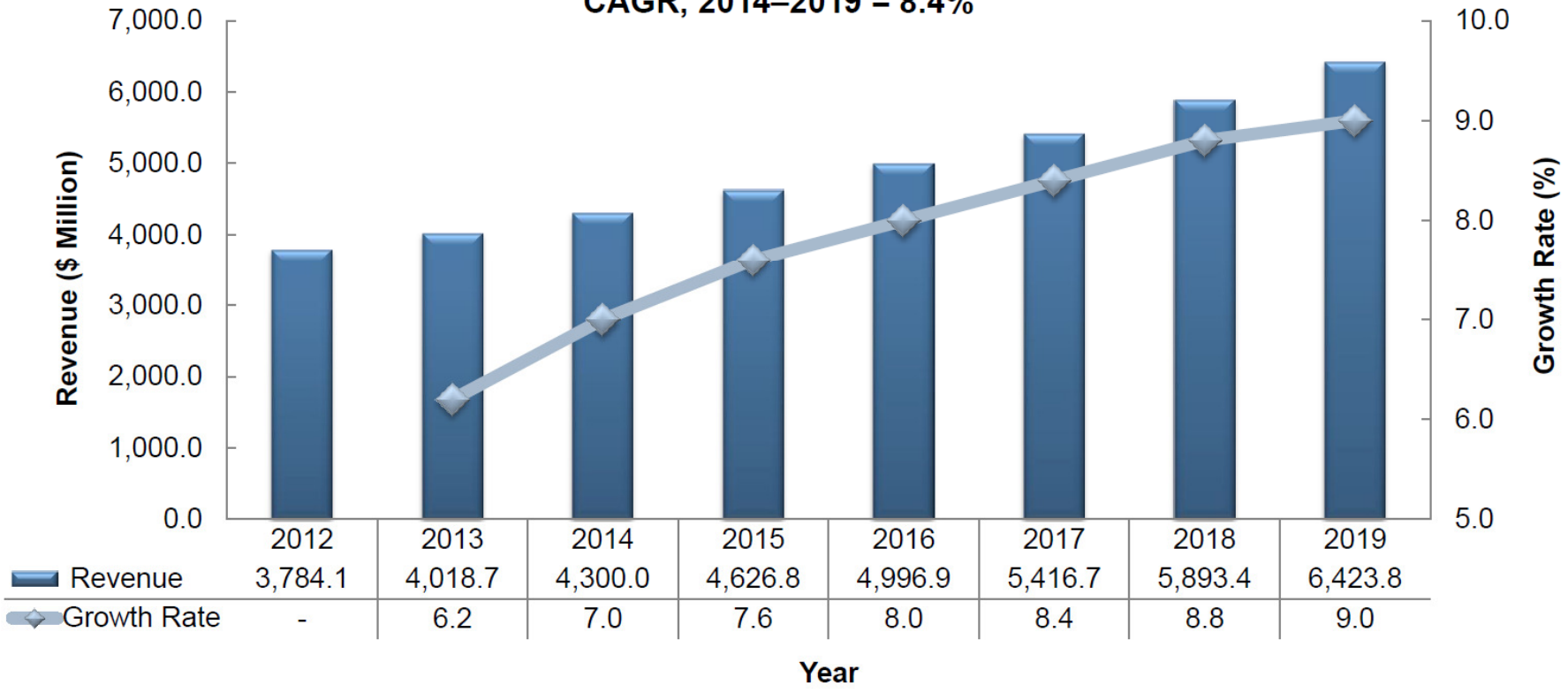
Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Data Centre Cooling Market – Revenue Forecast

Key Takeaway: Growth in the data centre cooling market will be primarily driven by growth in the emerging markets.

Total Data Centre Cooling Market: Revenue Forecast, Global, 2012–2019

CAGR, 2014–2019 = 8.4%



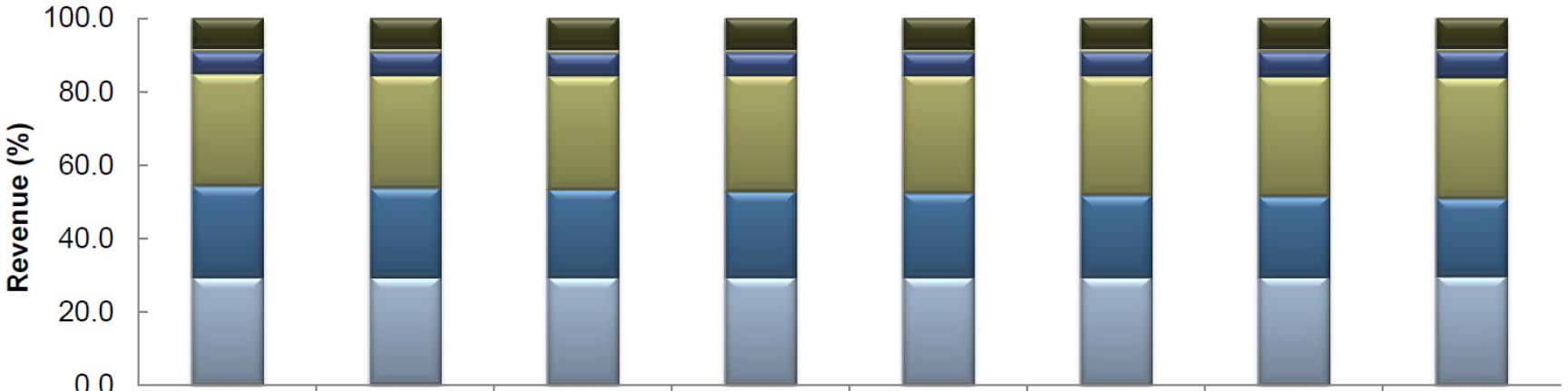
	2012	2013	2014	2015	2016	2017	2018	2019
Revenue	3,784.1	4,018.7	4,300.0	4,626.8	4,996.9	5,416.7	5,893.4	6,423.8
Growth Rate	-	6.2	7.0	7.6	8.0	8.4	8.8	9.0

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Data Centre Cooling Market—Per Cent Revenue Forecast by Region

Key Takeaway: Regions with the highest growth rates are China and APAC, growing at CAGRs of 11.4% and 9.7%, respectively, from 2014 to 2019.

Total Data Centre Cooling Market: Per Cent Revenue Forecast by Region, 2012–2019



	2012	2013	2014	2015	2016	2017	2018	2019
ROW	8.0	8.2	8.5	8.4	8.3	8.2	8.1	8.0
India	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
China	6.0	6.2	6.1	6.1	6.2	6.4	6.6	7.0
APAC	30.5	30.7	30.9	31.5	32.0	32.3	32.6	32.8
Europe	25.0	24.5	24.0	23.5	23.0	22.5	22.0	21.4
NA	29.5	29.4	29.5	29.5	29.5	29.6	29.7	29.8

Year

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Revenue Forecast by Region Discussion

North America

The biggest market for data centre cooling is North America, contributing 29.5% towards the total revenues in 2014. Increasing growth in the third-party colocation sector will drive revenue growth in the region.

Demand for applications such as mobile broadband, Big Data analytics, and social media has seen significant increases in the region. This trend is expected to continue over the forecast period, ultimately driving demand for cooling requirements.

Europe

The European data centre cooling market has started to recover from a dull performance post-2013. The most important market driving growth is the United Kingdom, followed by Germany and France. These markets, especially the United Kingdom, will see positive growth in white space volume in both the enterprise and hosting segments.

The UK market is one of the biggest recipients of external data centre investments globally. The IT floor space for cloud and hosting data centres in Germany is expected to increase at a CAGR of 33% from 2015 to 2016.

Source: Frost & Sullivan

Revenue Forecast by Region Discussion (continued)

APAC, China, and India

The APAC market (excluding China and India) was the biggest for data centre cooling in 2014, accounting for 30.9% of the global revenues. There has been a significant increase in growth rates recently; 2013 and 2014 witnessed growth rates of 6.9% and 7.7%, respectively. The high growth is expected to continue in 2015, at 9.7%, after which time, the growth rates will stabilise and remain at 9% levels throughout the forecast period.

China experienced a relatively dull performance in 2014, when the growth rate came down to 5.3% compared to a strong 2013, which grew at 9.7%. The dull performance in 2014 was caused by a sharp slowdown in its economy, which grew at its slowest pace in 24 years. The growth rate is expected to pick up in 2015 to reach 7.6%. The last 3 years of the forecast period are expected to register double-digit growth; where growth in 2019 is expected to be 15.6%.

The Indian data centre cooling market is extremely small with only 1.0% revenue contribution. The market grew by 7.0% in 2014 and high growth is expected throughout the forecast period, especially post-2016.

Rest of the World

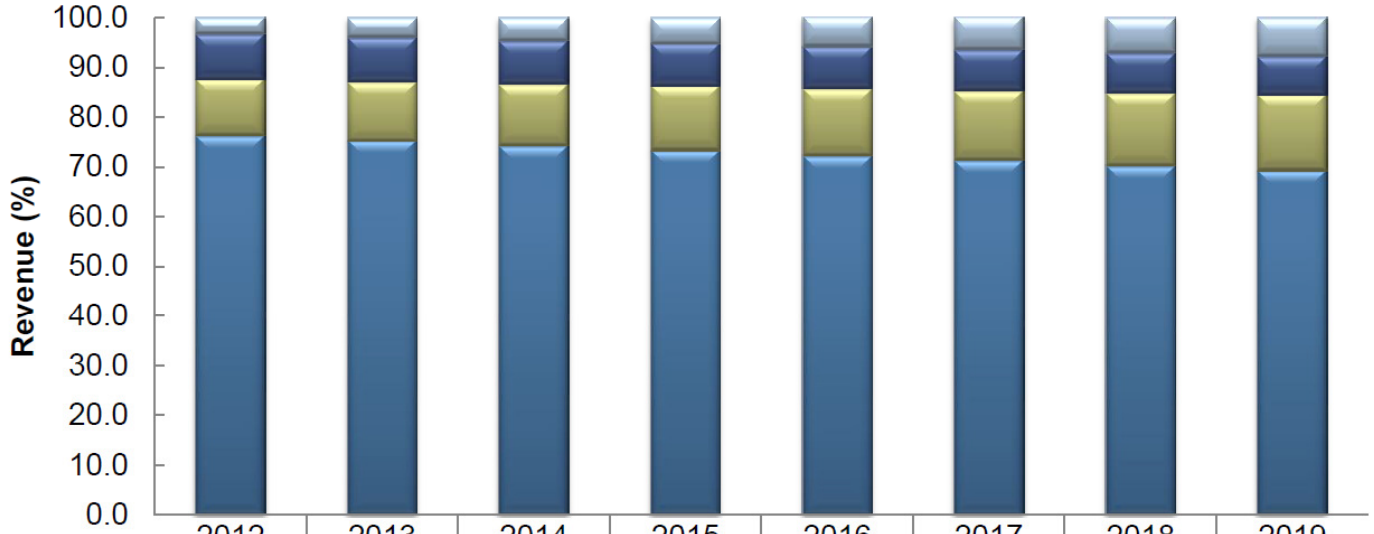
The market experienced good growth in 2014, growing at 10.9% compared to 8.9% in 2013. Key areas of growth were the Middle East, especially Dubai and the United Arab Emirates (UAE), and Latin America. However, growth rates are expected to remain moderate, at a 7% level, until the end of the forecast period. Latin America will be a key growth engine, where opportunity levels in Brazil, especially in São Paulo; Mexico; and Chile are expected to increase over the next couple of years.

Source: Frost & Sullivan

Data Centre Cooling Market—Per Cent Revenue Forecast by Cooling Type

Key Takeaway: The conventional cooling segment dominates market revenues, whereas the advanced cooling and high density cooling segments are expected to register the highest CAGRs.

Total Data Centre Cooling Market: Per Cent Revenue Forecast by Cooling Type, Global, 2012–2019



	2012	2013	2014	2015	2016	2017	2018	2019
Advanced Solutions	3.3	3.9	4.5	5.2	5.8	6.4	7.0	7.7
Airside Components & Chillers	9.1	9.0	8.8	8.6	8.4	8.2	8.1	7.9
High Density Cooling	11.3	11.8	12.3	12.9	13.4	14.0	14.6	15.1
CRAC/CRAH	76.3	75.3	74.3	73.4	72.4	71.4	70.3	69.3

Year

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Data Centre Cooling Market—Revenue Forecast by Cooling Type

Total Data Centre Cooling Market: Revenue Forecast by Cooling Type, Global, 2012–2019

Year	CRAC/CRAH ($ Million)	High Density Cooling ($ Million)	Airside Components & Chillers ($ Million)	Advanced Solutions ($ Million)
2012	2,886.9	427.8	345.5	123.8
2013	3,026.8	475.2	359.9	156.8
2014	3,196.5	530.7	377.9	194.9
2015	3,393.9	596.3	398.1	238.6
2016	3,615.7	671.6	420.7	288.9
2017	3,865.9	757.5	446.3	347.0
2018	4,145.4	858.4	475.1	414.4
2019	4,453.4	972.7	506.3	491.4
CAGR (%)	**6.9**	**12.9**	**6.0**	**20.3**

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Revenue Forecast by Cooling Type Discussion

- Traditional cooling systems still dominate market revenues and will continue to have a big impact in the medium term. The majority of the end users prefer proven traditional cooling methods such as CRAC/CRAH. However, concerns regarding energy efficiency, running costs, and total cost of ownership are expected to bring an eventual shift towards non-conventional cooling methods.
- The global data centre cooling market revenue is split between retrofit and new builds. With retrofits, the goal is to address hot spots by increasing cooling capacity. However, end users' space constraints force them to look at cooling technologies that would address both cooling and space issues.
- There are two different scenarios in the retrofit market. In one, there is a big change over, where most of the assets are replaced. In the other, there is the gradual change where the refresh rate is about every 5 years.
- Traditional cooling methods usually drive revenues in the former scenario. Space is a constraint in the latter scenario, thus, end users are more open towards exploring advanced solutions.
- Consolidation in data centres, especially in the healthcare and institutional segments, has forced end users to focus strongly on optimising their internal processes, such as air-flow and rack management. These trends will act as driving forces for the adoption of alternative cooling technologies.
- Liquid (immersion) cooling is still in its infancy and is facing scepticism from end users. However, there are a few early adopters and once the tangibility of this solution is proven, it will gain significant traction with an increase in installed base.

Source: Frost & Sullivan

Market Share Analysis

The top 3 companies together account for 69% of the total market share. Emerson Network Power is the clear leader with 31% market share, followed by Stulz with 21%.

Emerson's strength is in its wide range of product offerings covering all end-user segments.

Stulz has a strong presence in Europe and APAC, except in Southeast Asia. However, its market share in North America is quite low. It has displayed strong sales in CW-based units and floor-mount units, whereas its performance in "in-row" cooling has been weak.

APC by Schneider Electric has a strong presence in North America and Europe. Its acquisition of Uniflair has strengthened its position in Europe and the MEA region. However, it is considered as a Tier II participant in the APAC region.

The market share of Tier I participants has been stable in recent years, with no major competition from Tier II participants.

Total Data Centre Cooling Market: Company Market Share Analysis of Top 4 Participants, Global, 2014

Companies	Revenue ($ Million)
Emerson Network Power	1,333.0
Stulz	903.0
APC by Schneider Electric	731.0
Rittal	215.0
*Others	1,118.0
Total	**4,300.0**

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Competitive Factors and Assessment

- The dynamics of data centre cooling is slowly changing, moving towards innovative methods and technologies. Some of the key competitive factors in this space are reliability, performance, and efficiency.
- The mission-critical nature of the market makes it relatively less price sensitive. However, it is an important factor when it comes to traditional cooling systems, in which case, brand value and price are key.
- There is an emerging trend where comfort cooling manufacturers are increasingly widening their thermal management operating solutions to enter the data centre cooling space.
- These manufacturers mainly compete on price. However, although they have products for data centre cooling, they lack expertise in this space.
- Companies such as York and Munters are trying to bring comfort cooling applications such as chillers, roof-top units, and air handlers into the data centre industry, especially in certain regions such as the Middle East and Africa.
- On the other hand, core data centre cooling manufacturers are shifting their focus towards advanced and innovative cooling. End-user awareness levels on alternative cooling methods, such as evaporative cooling and free cooling, have been increasing. There are some new entrants in this space as well.
- Market consolidation can be expected in the near future, where large, core data centre cooling manufacturers will collaborate with small, niche, advanced cooling companies. This will be driven by the increase in demand for advanced cooling solutions.

Source: Frost & Sullivan

North American Energy Saving and Performance Contracting Market

NA Energy Saving and Performance Contracting Market

Energy Saving and Performance Contracting Market: Market Engineering Measurements, North America, 2015

Market Overview

Market Stage	Market Revenue	Market Size for Last Year of Study Period	Base Year Market Growth Rate	Compound Annual Growth Rate
Growth	$6.59 Billion (2015)	$10.57 Billion (2022)	5.7% (2015)	6.9% (CAGR, 2015-2022)

Customer Price Sensitivity	Degree of Technical Change	Market Concentration	Degree of Competition
8 (scale:1 [Low] to 10 [High])	8 (scale:1 [low] to 10 [high])	46.2% (market share held by top 3 companies)	8 (active market competitors in base year)

Decreasing | Stable | Increasing

Note: All figures are rounded. The base year is 2015. Source: Frost & Sullivan

Market Definitions

Geographical Scope

- This research service covers North America, namely Canada and the United States.

Energy Saving and Energy Performance Contracting

- Energy saving and performance contracting covers a range of services. These include project design and engineering, audits, assistance in acquiring finance, equipment bidding and acquisition, installation and commissioning, measurement and verification (M&V), and training of personnel.
- The market can be broadly segmented by the type of contract that a supplier has with the end user, namely energy performance contracts (EPC) and energy saving contracts (ESC).
- The principal difference is that EPC goes beyond ESC. Where ESC is often based on a business model that guarantees energy supply, EPC (as defined for this research) is a business model for energy savings that strongly links the supplier's remuneration to energy savings performance and frees the end user from capital investment.
- Key features of an EPC are:
  - Stipulation of guaranteed or shared energy savings through estimated reductions in energy consumption.
  - Savings are measured by kilowatt hours (kWh) of energy used rather than dollars spent because electricity prices are affected by factors beyond the control of the contract.
  - Monetary savings are retained entirely by the client in a guaranteed savings contract and are split between the client and service provider in a share savings contract.

Market Definitions ……..(Continued)

- Key features of an ESC are:
  - Under such self-financed contracts, the service provider is not held financially liable for unrealized savings. Consequently, M&V is not required.
  - Such contracts are commonly termed as design and build or turnkey.
- Service providers offering energy saving and performance contracting can be broadly grouped into four types within the North American market, namely:
  - ESCOs
  - Utilities with an ESCO division
  - Equipment manufacturers
  - Engineering and design firms
- Within the ESC and EPC business models, many different arrangements and contract types exist. These include:
  - **Delivery Contracting:** The service company provides products such as heat, chilling, compressed air and electricity. The subject of the contract is not the energy value, like for example litres of oil, but the utility value.
  - **Chauffage:** This is a form of delivery contracting. In a chauffage contract, service fees are calculated based on energy costs minus monetary savings made with a guaranteed level of service also provided.

Source: Frost & Sullivan

Market Definitions ……..(Continued)

- **Comfort Contracting:** These contracts will go beyond the provision of energy for the level of comfort and take care of full maintenance, including a healthy indoor environment and aesthetics.
- **BOOT Model:** It involves an energy service company designing, building, financing, owning and operating the equipment for a defined period of time and then transferring this ownership across to the client.
- **First Out:** The energy service company is paid 100% of the energy savings until the project costs, including the profit, are fully paid. The exact duration of the contract will actually depend on the level of savings achieved. The greater the savings, the shorter the contract.
- **Shared Savings:** In the shared savings model, the energy service company provides financing for the investments, who in return gets a share of the savings. There is no standard split of the share of the service company versus the client, as it will depend on the length of the contract, the payback time, and the risks taken. It is most common that the cost savings are guaranteed in a shared savings EPC.
- **Integrated Energy Contracting (IEC):** This combines EPC and delivery contracting. When designing the project, demand side measures are planned as a priority and the remaining level of energy needs are covered by more energy efficient supply, when possible. The contract is simpler than a normal EPC, which reduces expenses.

Source: Frost & Sullivan

Market Definitions ……..(Continued)

Vertical Market Analysis

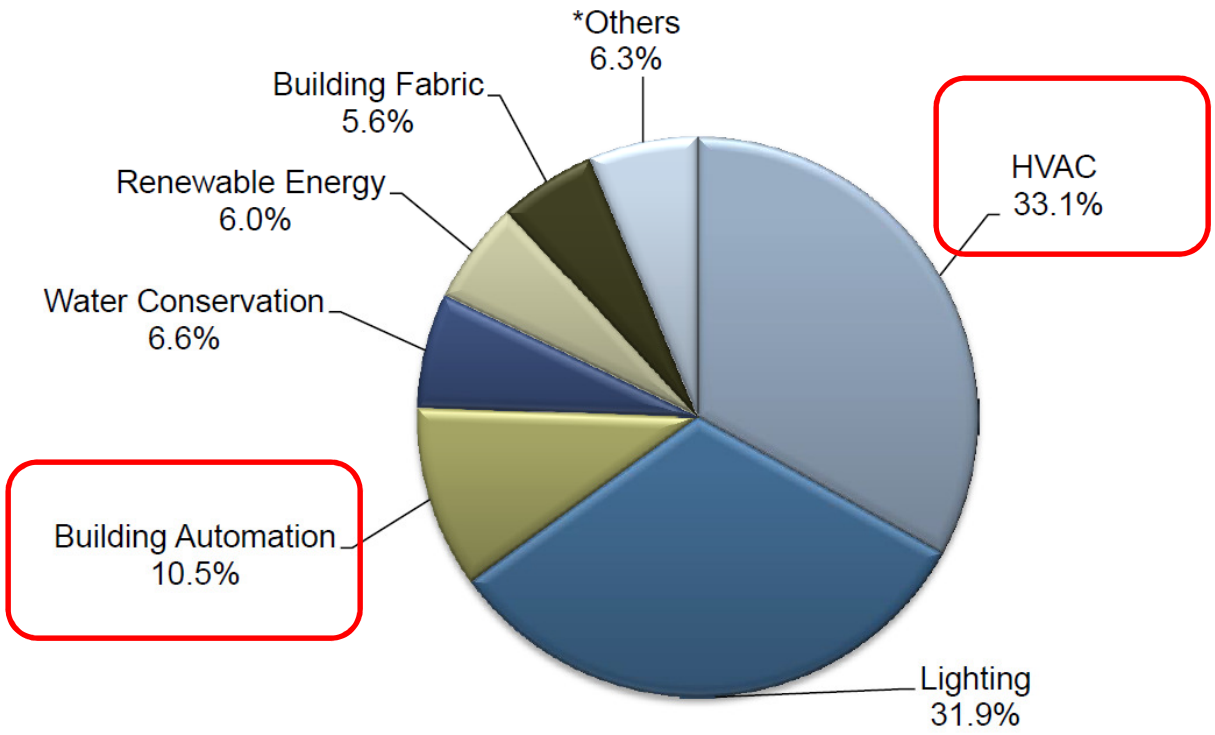
- Energy saving and performance contracts are offered to a wide range of sectors although for the purpose of this analysis we have grouped these into seven key vertical markets.
- Where possible, additional information on each of these vertical markets is also provided based on the key industries that reside within them.
  - Federal (office buildings, prisons, military facilities)
  - State/Provincial/Municipal
  - K-12 schools
  - Further education (higher education and universities)
  - Healthcare (large and small hospitals and other facilities)
  - Public housing
  - Commercial (offices, data centers) and industrial (factories, laboratories)

Source: Frost & Sullivan

Market Segmentation by Energy Conservation Measure

Key Takeaway: HVAC and lighting account for two-thirds of energy conservation measures.

Energy Saving and Performance Contracting Market: Percent Revenue Breakdown by Energy Conservation Measure, North America, 2015



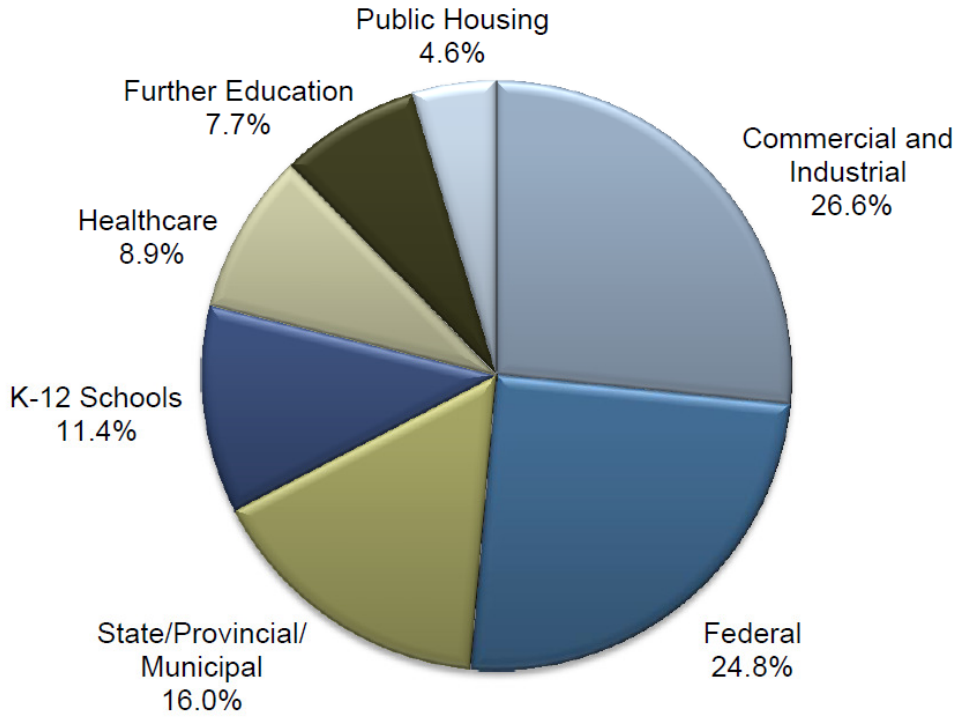
*Others include CHP and microgrids.

Note: All figures are rounded. The base year is 2015. Source: Frost & Sullivan

Market Segmentation by Vertical Market

Key Takeaway: Commercial, industrial, and federal account for over half of the market.

Energy Saving and Performance Contracting Market: Percent Revenue Breakdown by Vertical Market, North America, 2015

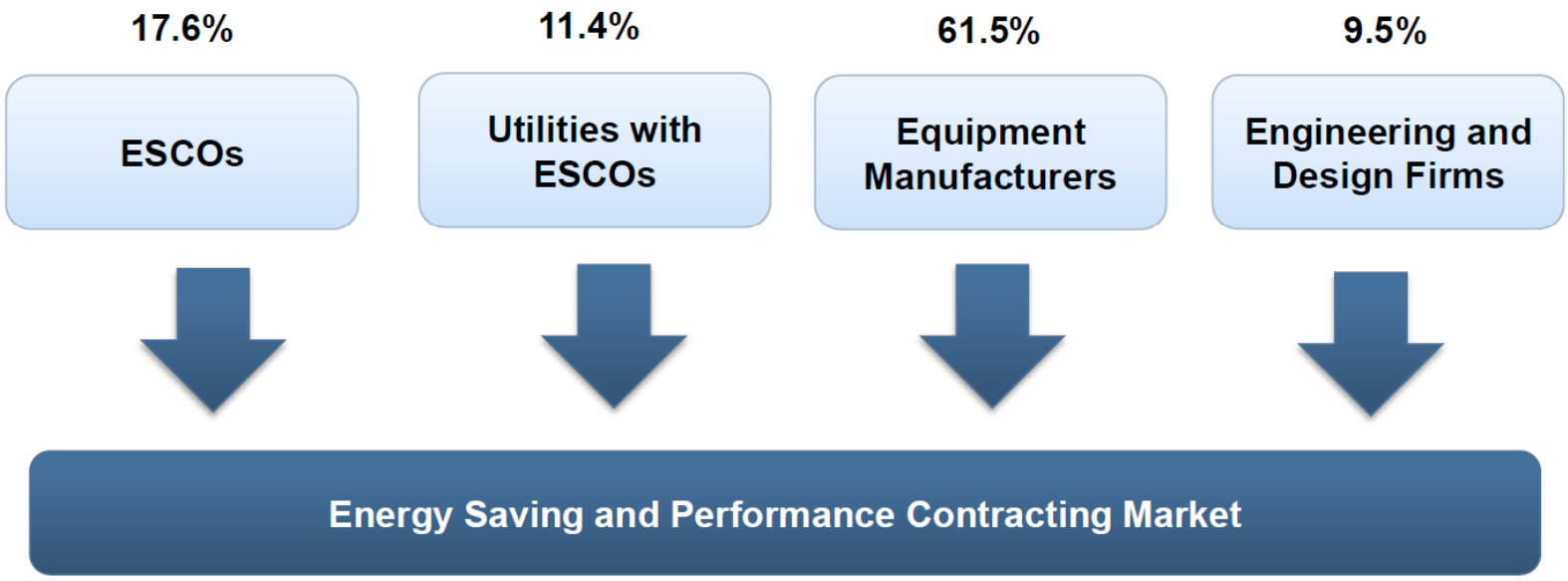


Note: All figures are rounded. The base year is 2015. Source: Frost & Sullivan

Competitive Structure by Type of Supplier

Key Takeaway: Equipment manufacturers account for majority of revenues.

Competitive Structure: Percent of Sales by Type of Supplier, North America, 2015



Source: Frost & Sullivan

Market Drivers

Energy Saving and Performance Contracting Market: Key Market Drivers, North America, 2016-2022

Drivers	1–2 Years	3–4 Years	5-7 Years
Specific legislation and regulations	H	H	H
Asset renewal	H	H	H
Favorable government policies	H	M	M
Proactive regional policies	M	M	H
Ability to generate quick returns with certain ECMs	M	M	H
Incentives to stimulate energy efficient practices	M	M	M
Guarantees offered with performance contracting	M	M	M
Limited capital available for investment	M	M	M
Environmental stewardship	L	L	M

Impact Ratings: H = High, M = Medium, L = Low

Source: Frost & Sullivan

Market Restraints

Energy Saving and Performance Contracting Market: Key Market Restraints, North America, 2016–2022

Restraints	1–2 Years	3–4 Years	5-7 Years
Payback times	H	H	H
Regional restrictions	M	M	M
Customer sophistication	M	M	M
Issue of holding debt on the balance sheet	M	M	M
Canadian market hit by election malaise	M	L	L

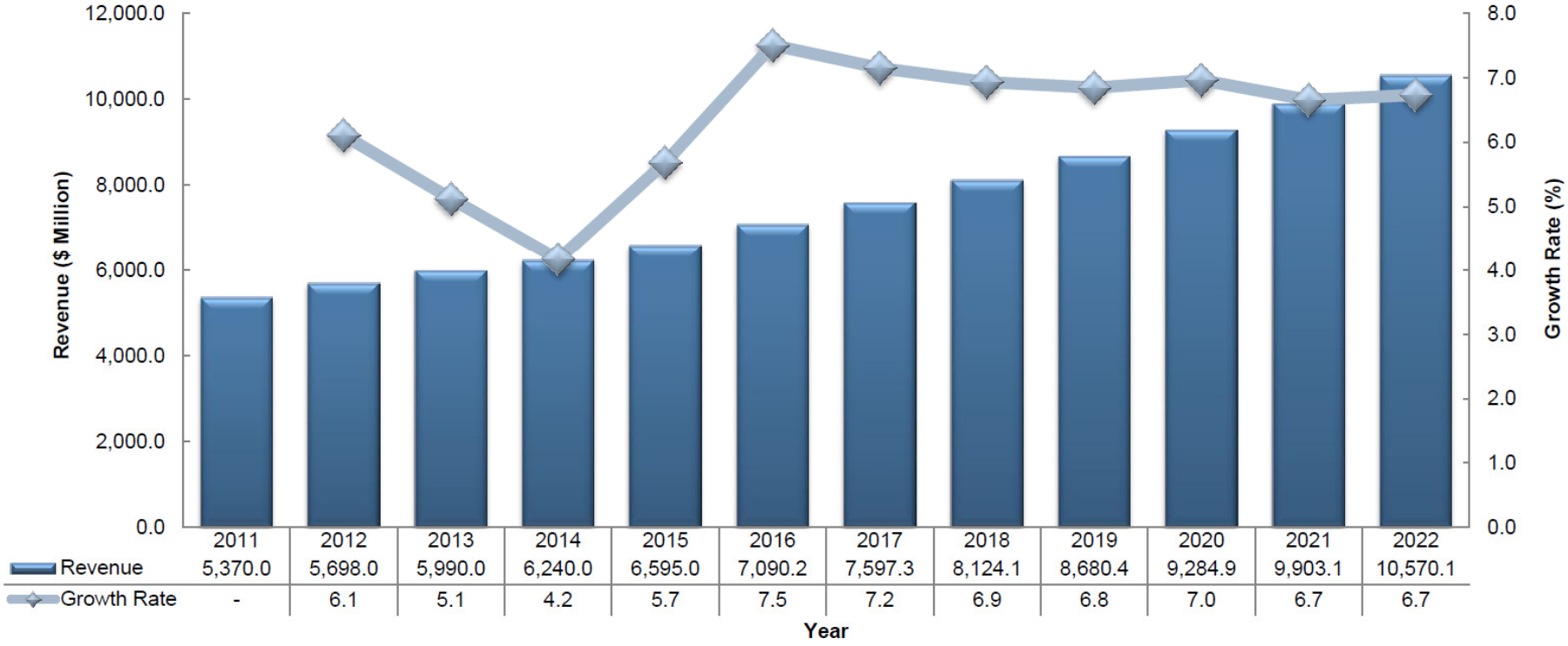
Impact Ratings: H = High, M = Medium, L = Low

Source: Frost & Sullivan

Revenue Forecast

Key Takeaway: Revenue growth accelerates after a period of market slowdown.

Energy Saving and Performance Contracting Market: Revenue Forecast, North America, 2011-2022
CAGR = 6.9%



Note: All figures are rounded. The base year is 2015. Source: Frost & Sullivan

Revenue Forecast Discussion

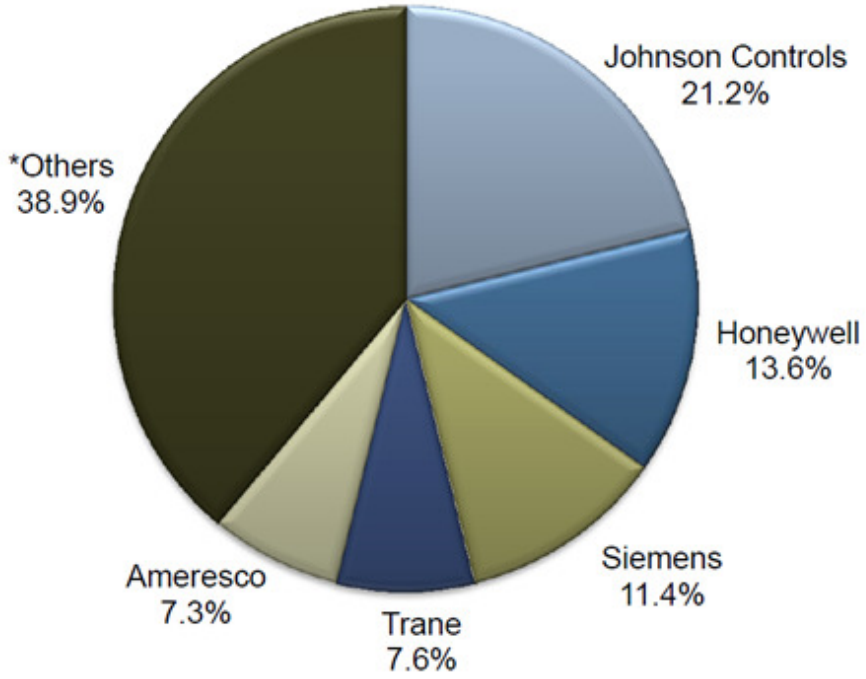
- The North American Energy Saving and Performance Contracting market has performed strongly in recent years. Driven primarily by federal initiatives in both Canada and the United States, the sector expanded from $5.37 billion in 2011 to $6.59 billion in 2015.
- Actions within the United States have been especially notable where the Presidential Performance Contracting Challenge has been the main driver. Some $2 billion for federal projects was announced in 2011 with an additional $2 billion in 2014. Such a level of investment towards performance contracting has helped minimize the slowdown that has occurred in the Canadian market during this period. This has had the effect of reducing overall growth, however, from 6.1% in 2012 to 4.2% in 2014.
- Looking ahead the prospects for the North American market remain good despite a number of restraints, notably low gas and oil prices. Actions such as a recent Presidential Executive Order in the United States for at least 15% of federal buildings to consume zero net energy by 2030, as well as the announcement in 2016 of a Better Buildings Initiative focused at the commercial sector, will be crucial. Equally, with the change in government in Canada in late 2015, a more proactive approach towards energy saving actions can be expected.
- The impact of such drivers are set to spur annual growth in the ESC/EPC market to 7.5% by 2016 when revenues are set to reach $7.09 billion. Thereafter, growth is set to moderate slightly, in large part reflecting completed projects in sectors such as education and healthcare, although still remain at around 6.6% to 6.9% per annum to deliver a total market valued at $10.57 billion in 2022.
- Although the market is set to benefit from many more smaller buildings taking up performance contracts, the key barrier will remain the C&I sector where EPC will remain restricted and ESC will dominate.
- The CAGR for the period 2015 to 2022 is forecast at 6.9%.

Source: Frost & Sullivan

Market Share

Key Takeaway: The market is dominated by a number of large equipment suppliers.

Energy Saving and Performance Contracting Market: Percent of Sales, North America, 2015



In total there are 40-50 companies in this market.

Note: All figures are rounded. The base year is 2015. Source: Frost & Sullivan

Market Share Analysis

- The supply side market is dominated by a small number of companies, all with an interest in equipment supply.
- The established leader is Johnson Controls, whose broad range of interests and experience gives it an estimated 21.2% of revenues in 2015.
- The next three spots are also taken by companies with a background in equipment manufacture, namely Honeywell (13.6%), Siemens (11.4%), and Trane (7.6%). Again, this further illustrates the importance of access to technology when operating in this market.
- The only major non-equipment company of note is Ameresco with 7.3%. Operating as a dedicated ESCO, Ameresco has regional and sectoral strengths.
- The remaining 38.9% of revenues include a number of other equipment manufacturers as well as ESCOs and utilities with their own ESCOs.
- Regionally, a large number of engineering and design firms are present in the market. These often focus on particular states or provinces, as well as on particular verticals.

Energy Saving and Performance Contracting Market: Company Market Share Analysis of Top 5 Participants, North America, 2015

Company	Revenue ($ Billion)
Johnson Controls	1.40
Honeywell	0.90
Siemens	0.75
Trane	0.50
Ameresco	0.48
*Others	2.57
Total	**6.59**

Note: All figures are rounded. The base year is 2015. Source: Frost & Sullivan

Competitive Environment

Energy Saving and Performance Contracting Market: Competitive Structure, North America, 2015	
Number of Companies in the Market	40-50
Competitive Factors	Competitive offer, customer understanding, reputation, relationship building, forward thinking, skill base
Key End-user Groups	Commercial/industrial, federal, state/provincial/municipal, K-12 schools, healthcare, further education, public housing
Major Market Participants	Johnson Controls, Honeywell, Siemens, Trane, Ameresco
Market Share of Top 5 Competitors	61.1%
Other Notable Market Participants	ConEdison Solutions, Constellation NewEnergy, Ecosystem, ESG, MCW, Noresco, Pepco, Schneider
Supply Structure	Equipment manufacturers, ESCOs, utilities with ESCOs, engineering and design firms

Source: Frost & Sullivan

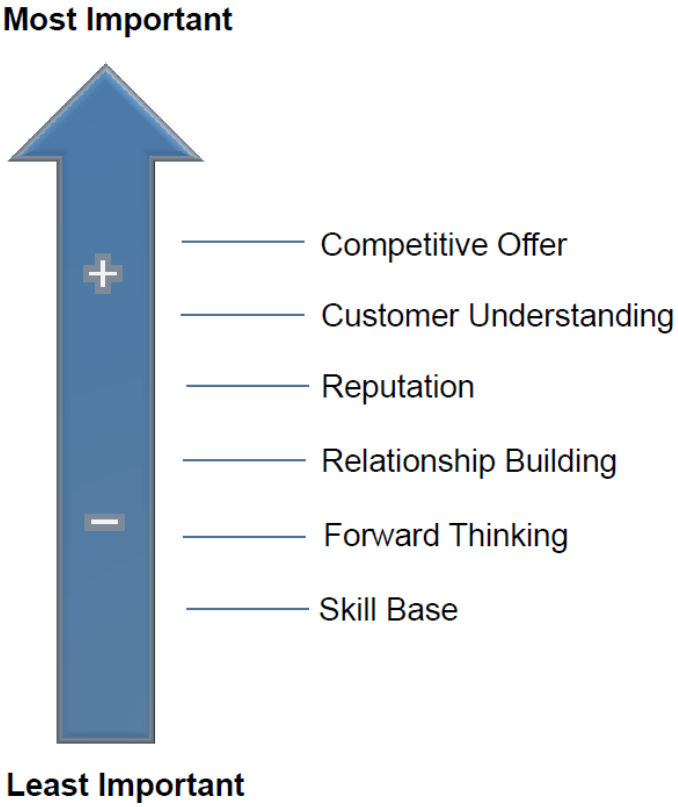
Competitive Factors and Assessment

- Those operating in the North American market can be broadly split into two groups, Tier I and Tier II companies.
- Tier I companies are large multinational concerns with national and regional interests. They typically have interests in wider technology markets and associated services. All have extensive experience of energy saving and performance contracting. They account for around 70% of revenues.
- Key participants include those with an equipment background such as Honeywell, JCI, Schneider, Siemens, Trane, and those with an ESCO background—notably Ameresco and Noresco.
- Tier II companies are smaller concerns. Although some operate nationally, most have strengths in particular regions. Engineering and design firms are an important group within this market, as are smaller ESCOs and utilities with ESCOs. Tier II companies account for around 30% of revenues.
- Key participants in this market include ESCOs ConEdison, Constellation, ESG, and Pepco, and engineering/design firms such as AECOM, Ecosystem, MCW, and Willdan.
- While the last couple of decades saw consolidation taking place within the market, this has slowed in recent years. One notable explanation of this is falling energy costs and the impact it has had on energy saving actions.
- Aside from smaller mechanical engineering and design companies entering the market offering energy saving and performance contracting alongside existing M&E work, interest from new entrants has been muted. Again, the impact of falling energy costs, growing price competition, and demands for project experience have made entering this market unattractive.
- Where new entrants are participating is in the energy saving market, where barriers to entry are weaker.

Source: Frost & Sullivan

Competitive Factors and Assessment (continued)

Energy Saving and Performance Contracting Market: Competitive Factors, North America, 2015

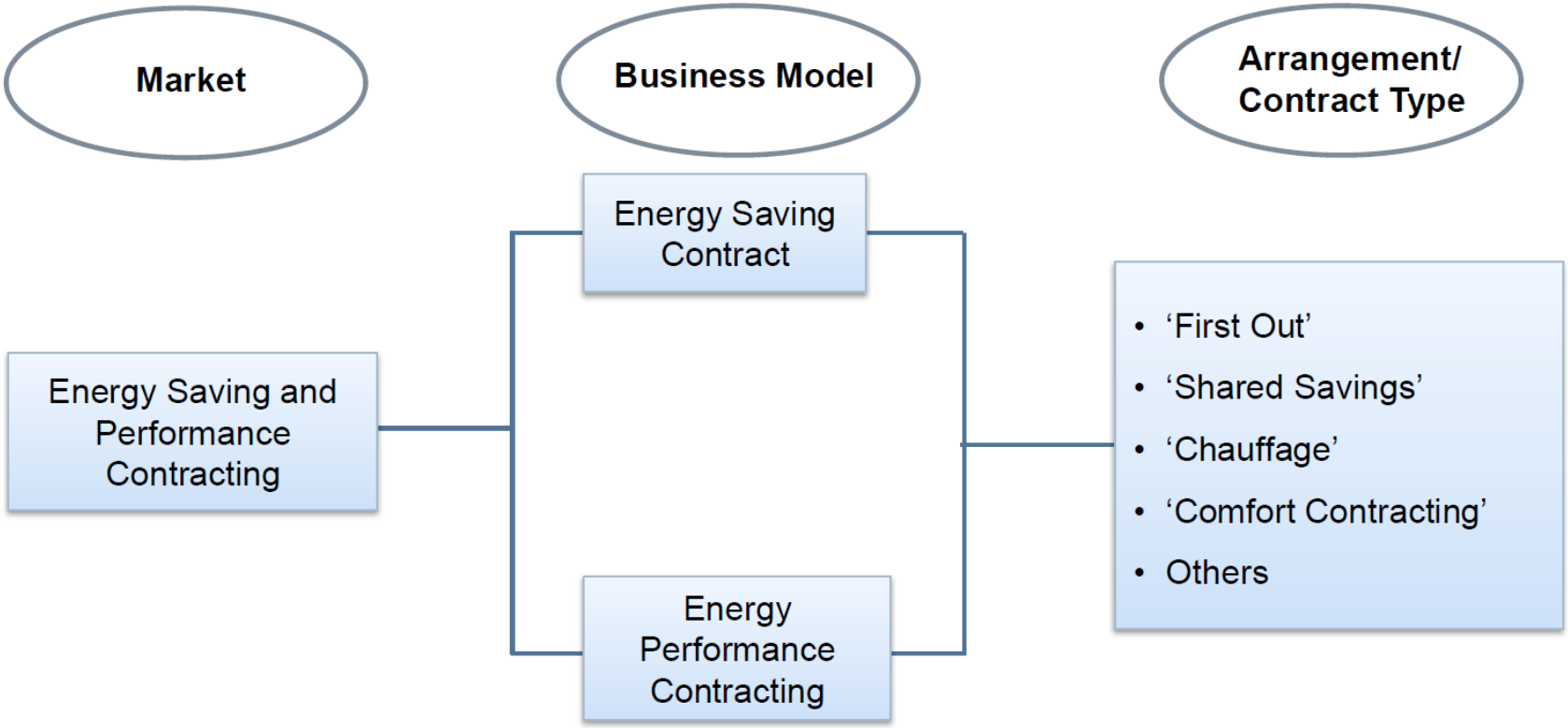


- **Competitive Offer:** Price has grown as a factor and the ability to be competitive has increased as a result.
- **Customer Understanding:** Knowing what a customer needs is vital for a project to be successful. This is especially true for those who are new to energy saving and performance contracting.
- **Reputation:** End users want to work with suppliers that have experience in their sector and the wider market. This is especially true of larger projects where risks can be greater.
- **Relationship building:** End users increasingly want suppliers to work with them long term. Offering services in addition to energy saving can prove attractive.
- **Forward Thinking:** Growing demands from clients is necessitating suppliers to offer a broader range of technologies and services.
- **Skill base:** A factor that can be very important for smaller suppliers.

Source: Frost & Sullivan

Typical Contract Types

Energy Saving and Performance Contracting Market: Typical Contract Types, North America, 2015



Note: Others includes delivery contracting, BOOT and Integrated Energy Contracting.

Source: Frost & Sullivan

European Energy Saving and Performance Contracting Market

European Energy Saving and Performance Contracting Market

Total Energy Savings Contract and Performance Contracting Market: Market Engineering Measurements, Europe, 2014

Market Overview

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

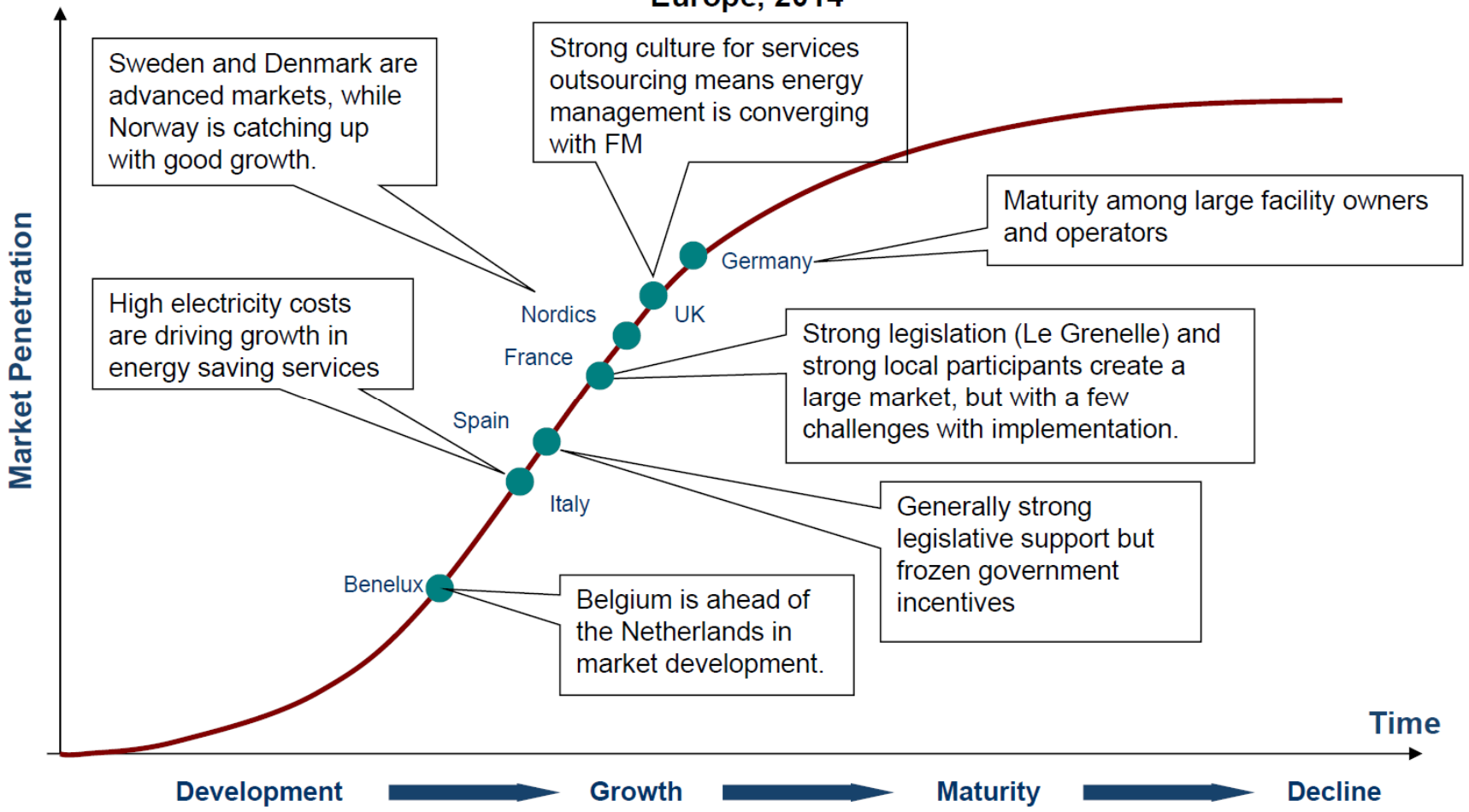
European Energy Saving and Performance Contracting Market – Key Findings

- The European energy savings contract and performance contracting market is still young and has high potential. Different regions are in different stages of development due to country-specific legal and political frameworks, incentive programmes, and the availability of project financing.
- Germany is the largest and most mature market in Europe. The Netherlands and Norway markets are underdeveloped, as lower energy costs result in less favourable ROI. Moreover, in many countries, building owners have different ways of improving energy efficiency, e.g., by implementing energy efficiency measures in-house without outsourcing.
- The public sector has been the most popular target for energy savings service providers due to the impact of EU directives on energy savings for public buildings, which makes the market more competitive. As winning projects in the public sector is likely to be harder in future, companies are focusing on long-term prospects for new, untapped areas of the private sector.
- In most countries, performance contracting is growing faster than energy savings. Energy performance contracting is most popular in the public sector due to the lack of finance in public institutions and the contract length. They represent less financial risk, while their energy consumption is more stable and, therefore, easier to predict.
- There are over 300 market participants from various backgrounds. With increased awareness of the business opportunities in performance contracting, new entrants from utility, engineering consultancy, and construction are trying to gain a foothold. Also, facility management (FM) companies continue to move into the space, offering energy efficiency services as an extension of their FM contracts. Their expertise in building management and their large customer base are advantages.
- Further developments in technologies supporting Web-based real-time measurement and verification, and integration with other smart technologies are expected to create further opportunities for building technology equipment manufacturers and emerging technology and service firms.

Source: Frost & Sullivan

Life Cycle Analysis by Country

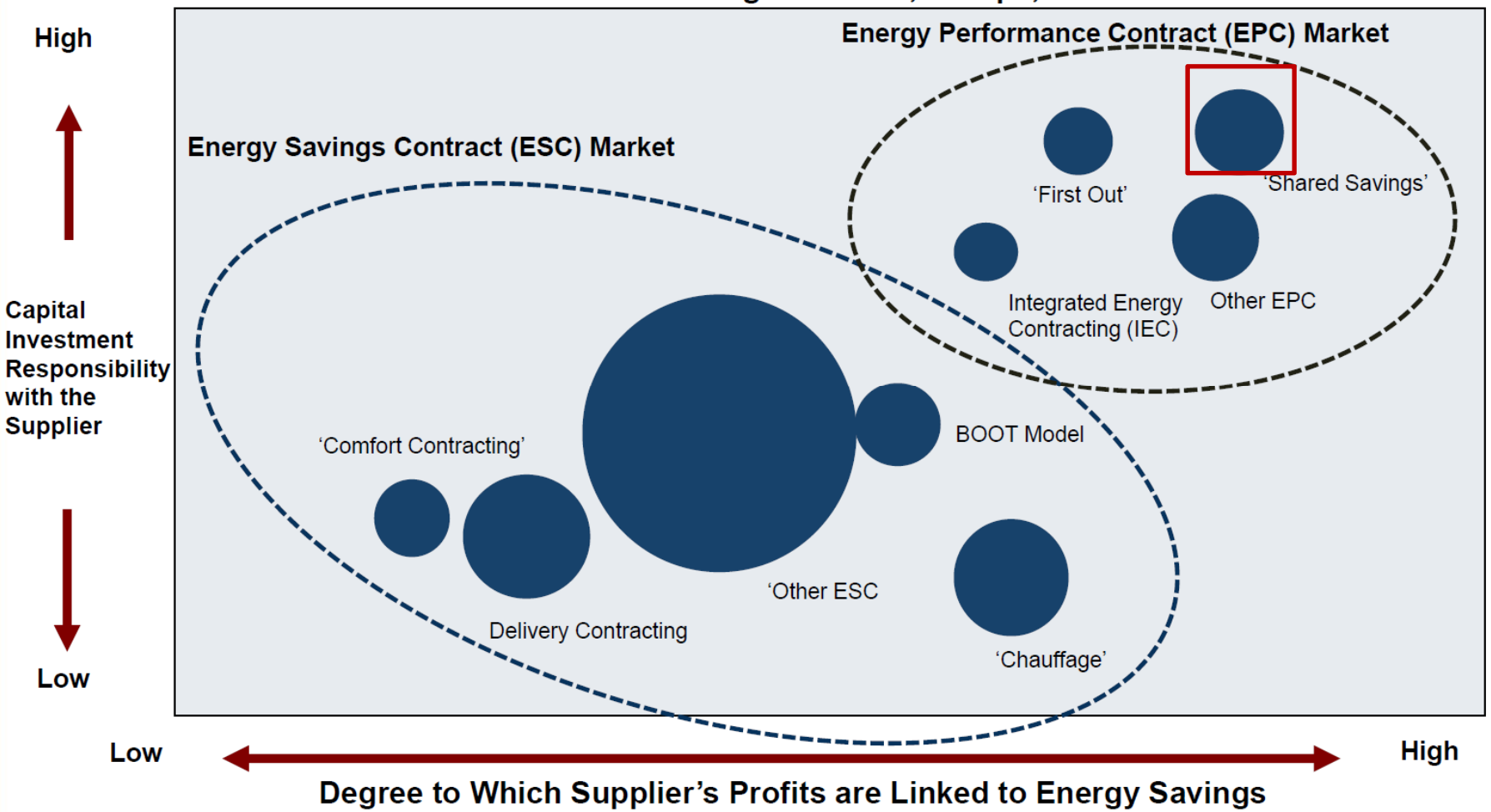
Total Energy Savings Contract and Performance Contracting Market: Life Cycle Analysis by Country, Europe, 2014



Source: Frost & Sullivan

Business Models: OEM Thrives on Shared Savings

Total Energy Savings Contract and Performance Contracting Market: Selection of Common Contract Models and Market Segmentation, Europe, 2014



Radius of circle indicates number of projects

Source: Frost & Sullivan

Market Drivers

Total Energy Savings Contract and Performance Contracting Market: Key Market Drivers, Europe, 2015–2020

Drivers	1–2 Years	3–4 Years	5-6 Years
Need to save costs through reduction of energy consumption creates demand for energy efficiency services, including energy savings contracts	H	H	H
Regulations and legislation including EU Directives drive changes in behaviour from both customers and suppliers	H	H	M
Need for compliance with CO_2 reduction targets and attaining green credentials benefits suppliers with complete offerings	M	M	M
Favourable financing options with little or no initial investment required from end users create demand for performance-oriented business models	M	M	M
The **boom of smart technology** and increasing building complexity exceed in-house capabilities to create an attractive proposition for service externalisation to energy professionals	L	M	M
Efforts by facilitators and associations lead to success in raising end-user awareness and procedural support for energy savings contract markets	L	L	L

Impact Ratings: H = High, M = Medium, L = Low

Source: Frost & Sullivan

Market Restraints

Total Energy Savings Contract and Performance Contracting Market: Key Market Restraints, Europe, 2015–2020

Restraints	1–2 Years	3–4 Years	5–6 Years
Lack of end-user education and the need for case studies and references	H	M	M
Lack of common definitions and harmonised processes across different European countries and EU member states	M	M	M
Interest in energy supply rather than demand-side and **difficulty in procurement procedures**, particularly in the public sector	M	M	L

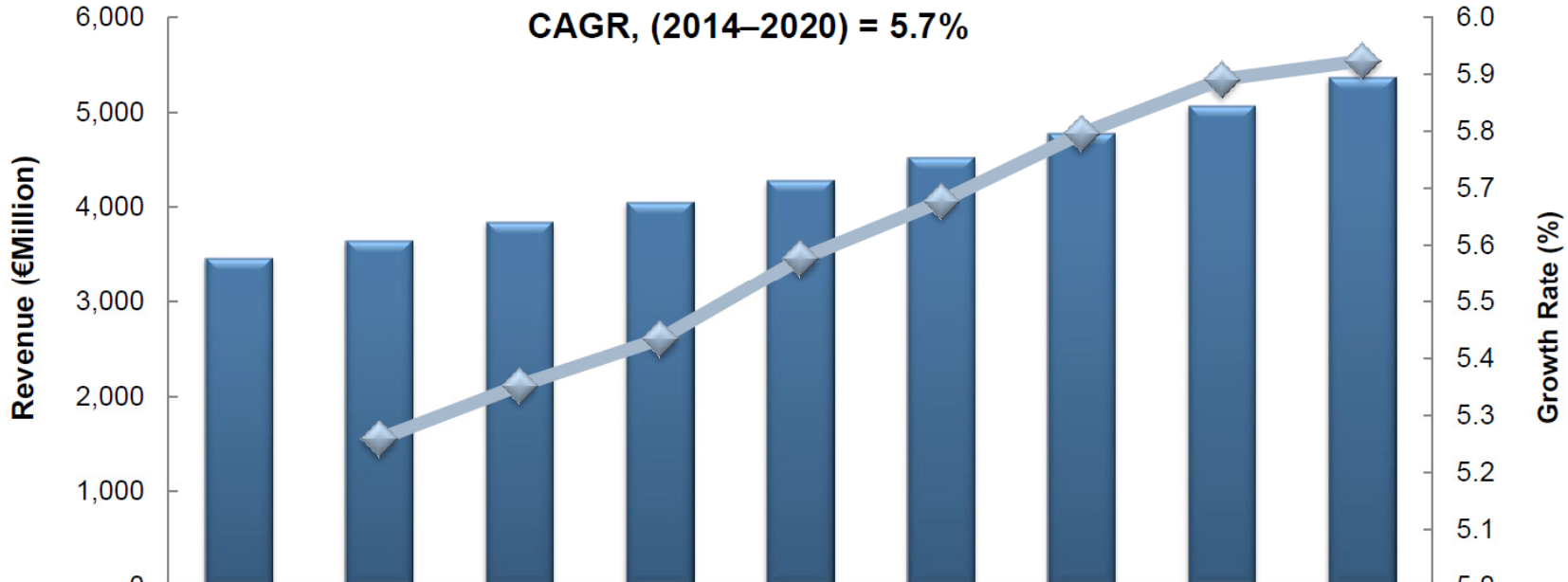
Impact Ratings: H = High, M = Medium, L = Low

Source: Frost & Sullivan

Revenue Forecast

Key Takeaway: The market is expected to experience robust growth of above 5% per annum throughout the forecast period.

Total Energy Savings Contract and Performance Contracting Market: Revenue Forecast, Europe, 2012–2020



	2012	2013	2014	2015	2016	2017	2018	2019	2020
Revenue	3,467.1	3,649.4	3,844.7	4,053.7	4,279.7	4,522.7	4,784.8	5,066.7	5,366.9
Growth Rate	-	5.3	5.4	5.4	5.6	5.7	5.8	5.9	5.9

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Revenue Forecast Discussion

- The European energy savings contract and performance contracting market was worth almost €4 Billion in 2014 and grew at over 5% from the previous year, continuing the trend of strong growth since the past few years.
- Growth is driven by the concept of providing guaranteed energy saving outcomes to customers. This follows the increasingly strong trend whereby building owners and operators are beginning to move away from investing in products, systems, and solutions and moving to buying outcomes through innovative service contracts.
- The key customer benefits include energy and cost savings, improved business efficiency and sustainability, and the ability to increase focus on core business activities by outsourcing energy management.
- Growth of above 5% per year is expected throughout the forecast period, with annual growth reaching almost 6% by 2020, and a CAGR of 5.7% from 2014 to 2020.
- Energy savings contracts and performance contracting drive significant savings can be seen in areas such as HVAC equipment, renewable energy, space usage, motion sensor and motor replacement, lighting retrofit, lighting controls, sensors, and internal and external LED lighting.

Source: Frost & Sullivan

Revenue Forecast by Country

Total Energy Savings Contract and Performance Contracting Market: Revenue Forecast by Country, Europe, 2012–2020

Year	UK (€ Million)	Germany (€ Million)	France (€ Million)	Italy (€ Million)	Spain (€ Million)	Benelux (€ Million)	Nordics (€ Million)
2012	559.6	1,073.1	718.0	421.0	162.8	237.5	295.1
2013	598.2	1,125.2	762.1	439.2	163.0	251.3	310.3
2014	638.2	1,180.9	809.0	459.7	163.2	266.5	327.2
2015	680.5	1,237.9	858.3	483.6	163.6	284.3	345.5
2016	725.1	1,298.8	911.4	510.0	165.4	304.1	364.9
2017	772.5	1,363.5	968.5	537.9	168.4	325.9	386.0
2018	823.5	1,433.0	1,030.8	566.9	172.0	350.2	408.4
2019	878.4	1,507.0	1,098.5	597.0	176.0	377.0	432.6
2020	937.1	1,585.0	1,172.6	627.3	180.4	406.2	458.3
CAGR % (2014–2020)	**6.6**	**5.0**	**6.4**	**5.3**	**1.7**	**7.3**	**5.8**

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Revenue Forecast by Country Discussion

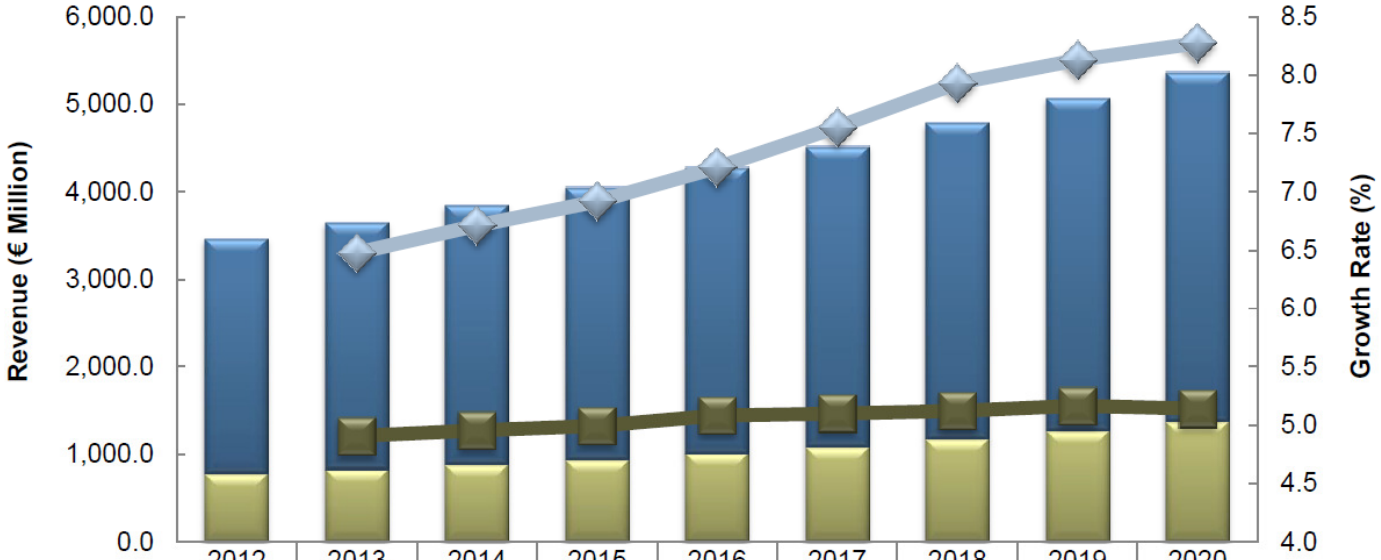
- Germany—as Europe's largest economy and with some of the strongest regulations for energy efficiency—is the largest market for energy services and is expected to remain so throughout the forecast period. Germany has a particularly strong market in the public sector, although it is also seeing significant revenue and strong growth in the private sector.
- The French market—being home to several of the leading European and global suppliers of energy management services—is the second-largest market in Europe, with the highest percentage of public sector revenue (61.7%) of any European country.
- All countries in Europe are expected to experience growth in both the ESC and EPC segments throughout the forecast period. In every country except the Nordic region, the growth for EPC is forecast to outstrip growth for ESC apart from Italy, where the growth will be the same for each. The Nordic region is expected to experience increasing growth in EPC but remain dominated by ESC, which is a well-established market with very high customer acceptance.
- As a general rule, the markets of northern Europe have a more embedded culture of outsourcing and tend to have a proportionally larger market for services such as FM and energy management. Some companies are responding to this and aligning their strategies at a more regional level. The Danish FM company ISS, for example, recently combined its Nordic and UK businesses into a single regional business for Northern Europe.
- However, some of the less penetrated markets of southern Europe such as Italy and southern France are expected to show strong growth during the forecast period as energy outsourcing models become more commonplace.

Source: Frost & Sullivan

Revenue Forecast by Service Type

Key Takeaway: Growth in the ESC segment is expected to be strong but flat at about 5% per year, while EPC growth is forecast to accelerate to over 8% per year by 2020.

Total Energy Savings Contract and Performance Contracting Market: Revenue Forecast by Service Type, Europe, 2012–2020



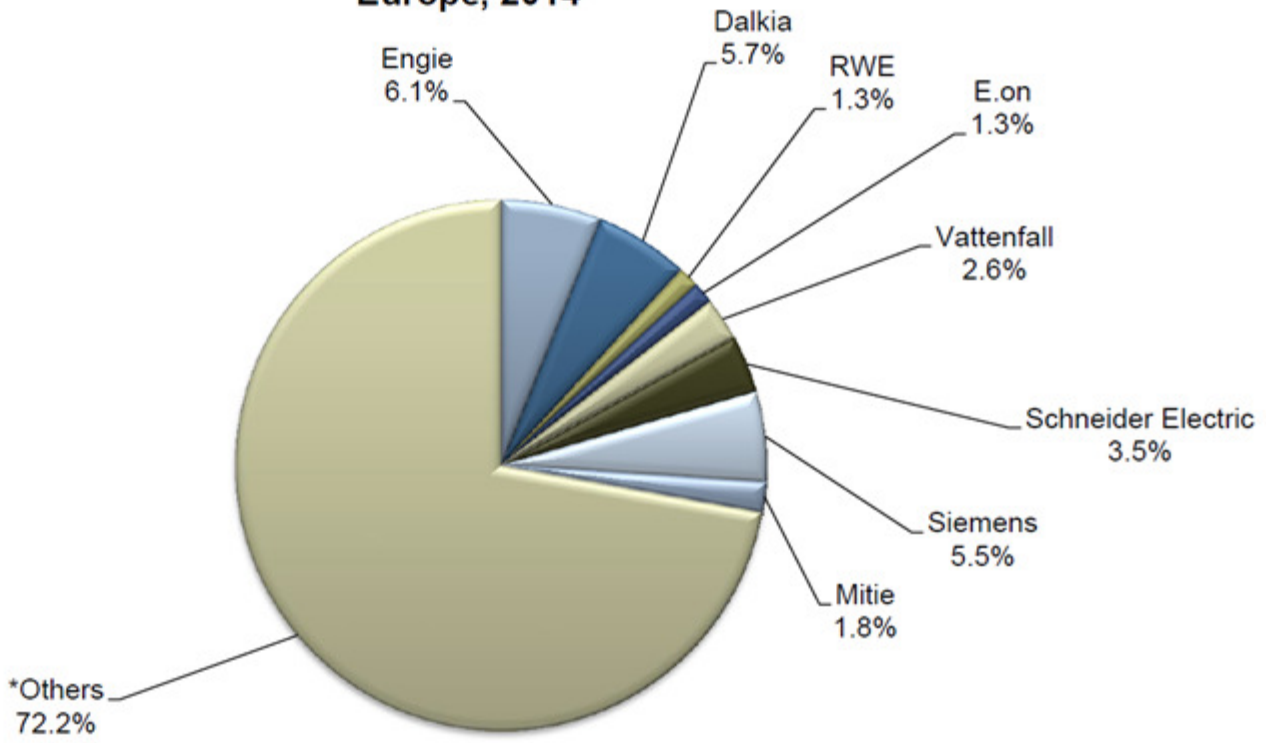
	2012	2013	2014	2015	2016	2017	2018	2019	2020
Energy Savings Contract Revenue	2,690.4	2,822.4	2,962.2	3,110.0	3,268.1	3,434.6	3,610.5	3,796.9	3,992.0
Energy Performance Contracting Revenue	776.7	827.0	882.6	943.6	1,011.6	1,088.1	1,174.4	1,269.8	1,374.8
Energy Performance Contracting Growth	-	6.48	6.71	6.92	7.21	7.55	7.93	8.13	8.27
Energy Savings Contract Growth	-	4.91	4.95	4.99	5.08	5.10	5.12	5.16	5.14

Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Market Share

Key Takeaway: The market is relatively fragmented, with the top 3 participants accounting for just 17.3% of the total revenue in 2014.

Total Energy Savings Contract and Performance Contracting Market: Per Cent Revenue Breakdown, Europe, 2014



Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Market Share Analysis

The top 3 participants contributed 17.3% of the total market revenue in 2014, showing that this market is still fairly fragmented.

Engie, which was rebranded in 2015 and previously operated as Cofely within the previously named GDF Suez, was the market leader in 2014 with 6.1%.

Dalkia—a very close competitor to Engie, with a similar background and operating model—holds the second place in the market with 5.7%.

Siemens and Schneider Electric occupy the third and fourth places, each coming from the positions of leading participants in markets for building technologies, and have expanded into service-based delivery to build strong positions in this market.

Beyond these market leaders, there is a complex and diverse mix of competitors. FM companies are expanding their portfolios and partnering with other hard service providers to offer energy saving services and performance contracting. Utilities are innovating with new models to drive growth in non-regulated markets.

Total Energy Savings Contract and Performance Contracting Market: Company Market Share Analysis of the Top 8 Participants, Europe, 2014

Company	Revenue (€ Million)
Engie	235
Dalkia	220
Siemens	210
Schneider Electric	135
Vattenfall	100
Mitie	70
RWE	50
E.On	50
*Others	2,775
Total	**3,845**

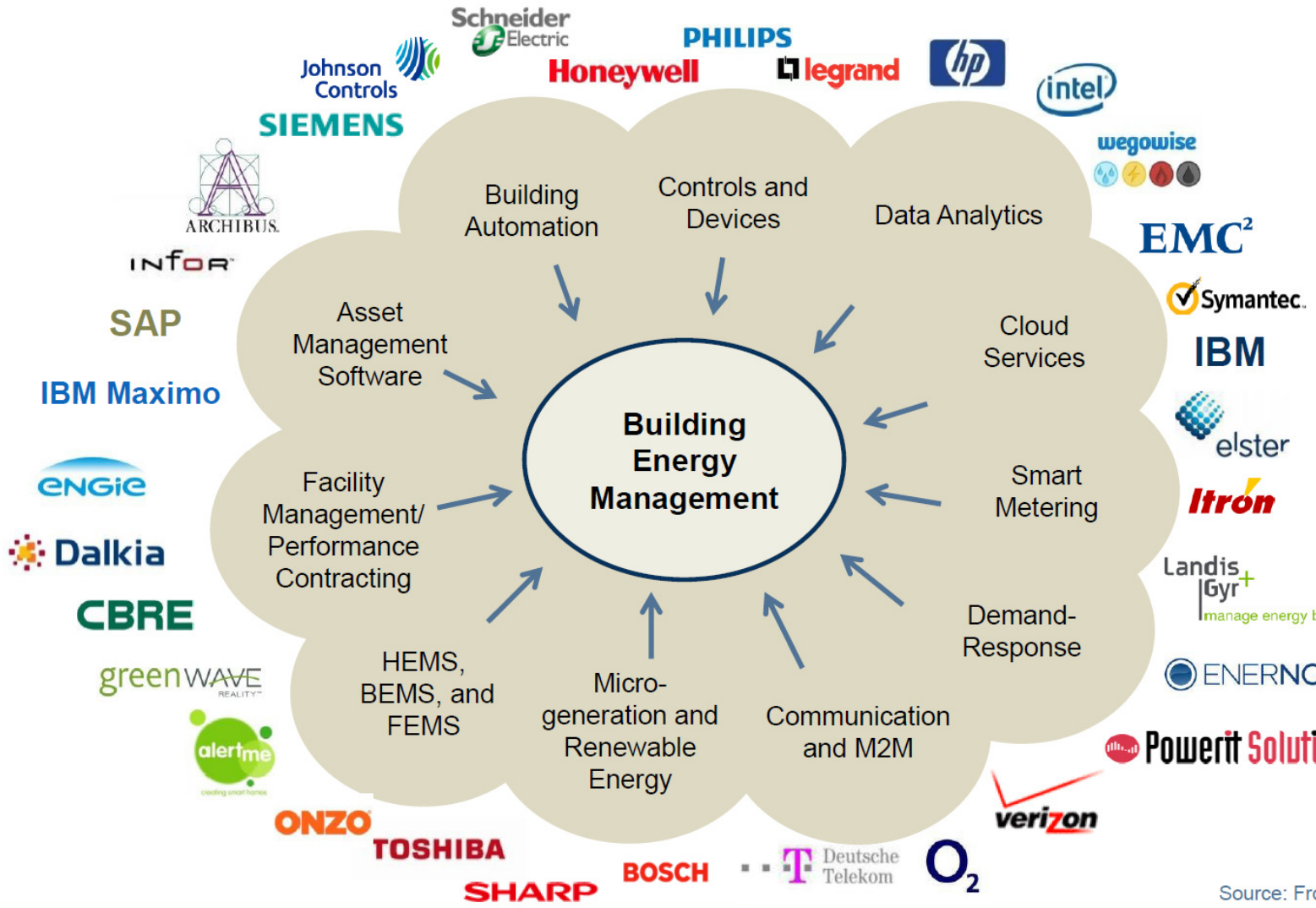
Note: All figures are rounded. The base year is 2014. Source: Frost & Sullivan

Competitive Environment

Total Energy Savings Contract and Performance Contracting Market: Competitive Structure, Europe, 2014	
Number of companies in the market	>300 with revenue greater than €1.0 Million
Competitive factors	Cost savings, performance, support, technological capability, service excellence, customer relationships
Key end-user groups	Government, Education, Healthcare, Retail, Hospitality, Industrial, and Offices
Major market participants	Cofely (GDF Suez, now rebranded as Engie), Dalkia, Siemens, RWE, E.On, Mitie, Vattenfall, Schneider Electric
Market share of top 3 competitors	17.3%
Other notable market participants	Centrica, Imtech, MVV, Bouygues, Eiffage, ISS, CBRE, Vinci, Fedesco, Acciona, Manutencoop, Kier Group, EMCOR UK, Spie, Ceresa, Siram, Sitec
Notable acquisitions and mergers	CBRE acquired Norland; ISS acquired GS Hall; EdF acquired Dalkia France; Engie acquired Balfour Beatty UK

Source: Frost & Sullivan

Competitive Convergence from Neighbouring Markets: Examples of Tier-1 Participants



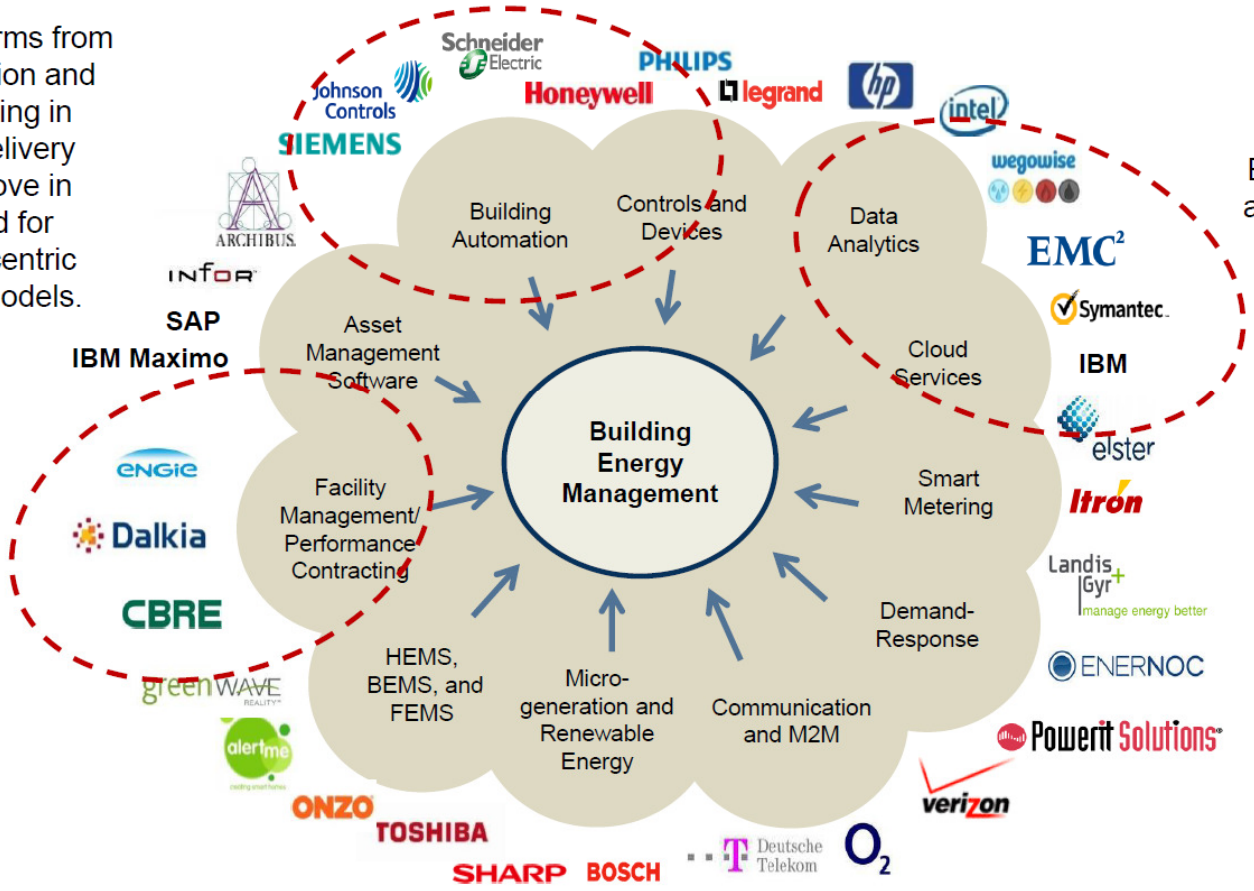
Source: Frost & Sullivan

Competitive Convergence from Neighbouring Markets: Complexity from Varying Service Models

Key Takeaway: New technology and service business models from neighbouring markets are making ESC and EPC more complex and attracting new participants.

Leading Tier-1 firms from building automation and BEMS are investing in service-based delivery capabilities to move in line with the need for more customer-centric EMS business models.

ESCOs and FM companies focus on service business models and aim to increase technical skills to dominate the ownership of customer relationships.



Cloud-based services, data analytics, remote monitoring, and Energy Savings as a Service concepts are changing the competitive landscape and bringing IT-based firms into service delivery.

Source: Frost & Sullivan

Patent Landscape Analysis and Review of Patents Relevant to Given Technology

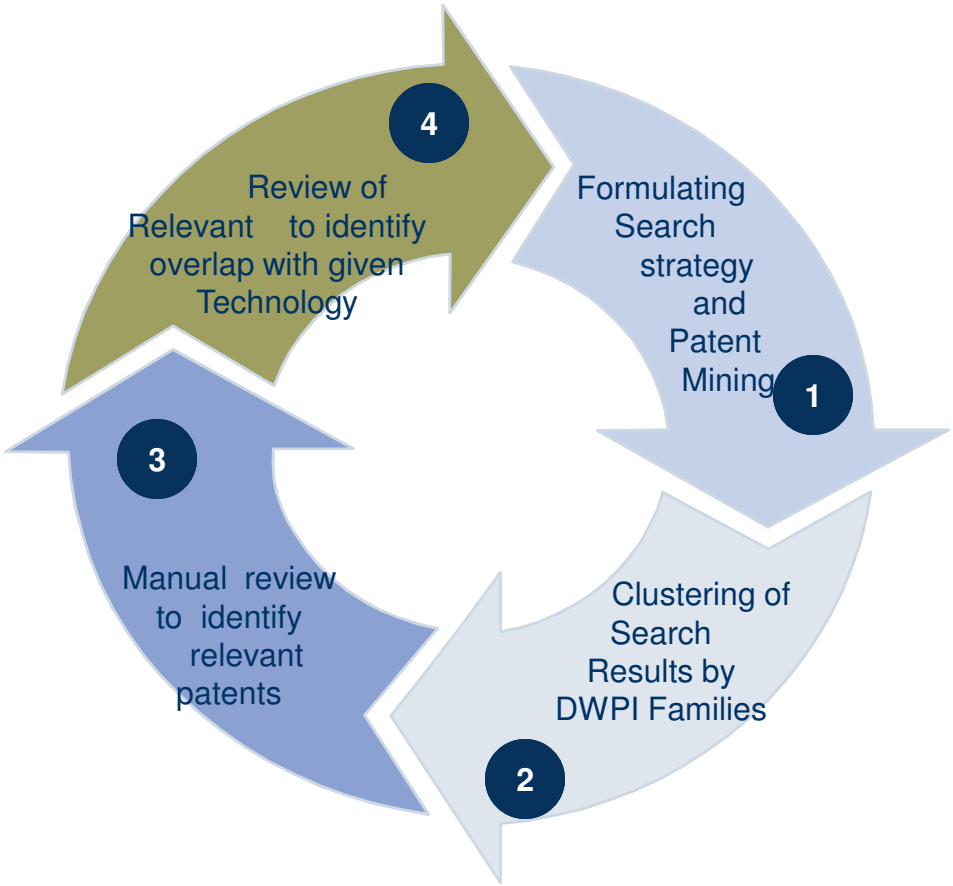
Patent search Scope

- Patent Mining Tool: Thomson Innovation
- Databases: US, EP, WIPO, Germany, France, Japan , China , Korea and Others
- Timeline: Last 20 Years (January 1, 1997 – April 20, 2017)
- Search Concepts: Following International Patent classification codes (IPC) and Key words were used for
  - Keywords: Chillers; Chilled Water; HVAC system; Controller; Control unit; cooling system control; cooling system controller; Adjustment module.
  - International patent classification codes
    - G05B : Testing or monitoring of control systems or parts thereof

- In the profiling section, only unique DWPI patent families# are covered.

- *The DWPI is a value-added patent database available through Thomson Innovation. The value of DWPI is the result of a thorough editorial process of classifying, abstracting, and indexing. Original titles and abstracts are rewritten to reveal the actual invention and highlight the main uses and advantages of the technology.
- #DWPI families are constructed based on a novelty principle, where new members have matching technical content with previous ones. The DWPI assembles information describing a patent family, starting with the new invention (basic patent) and adding information about patents for the same invention issued in other countries (equivalents).

Patent Landscape Analysis - Overall Approach



F&S formulated appropriate search strategy using keywords and classification codes to mine all patents/research papers wrt "Application of High Resolution Sensors in Cell culture and Tissue Morphology ".

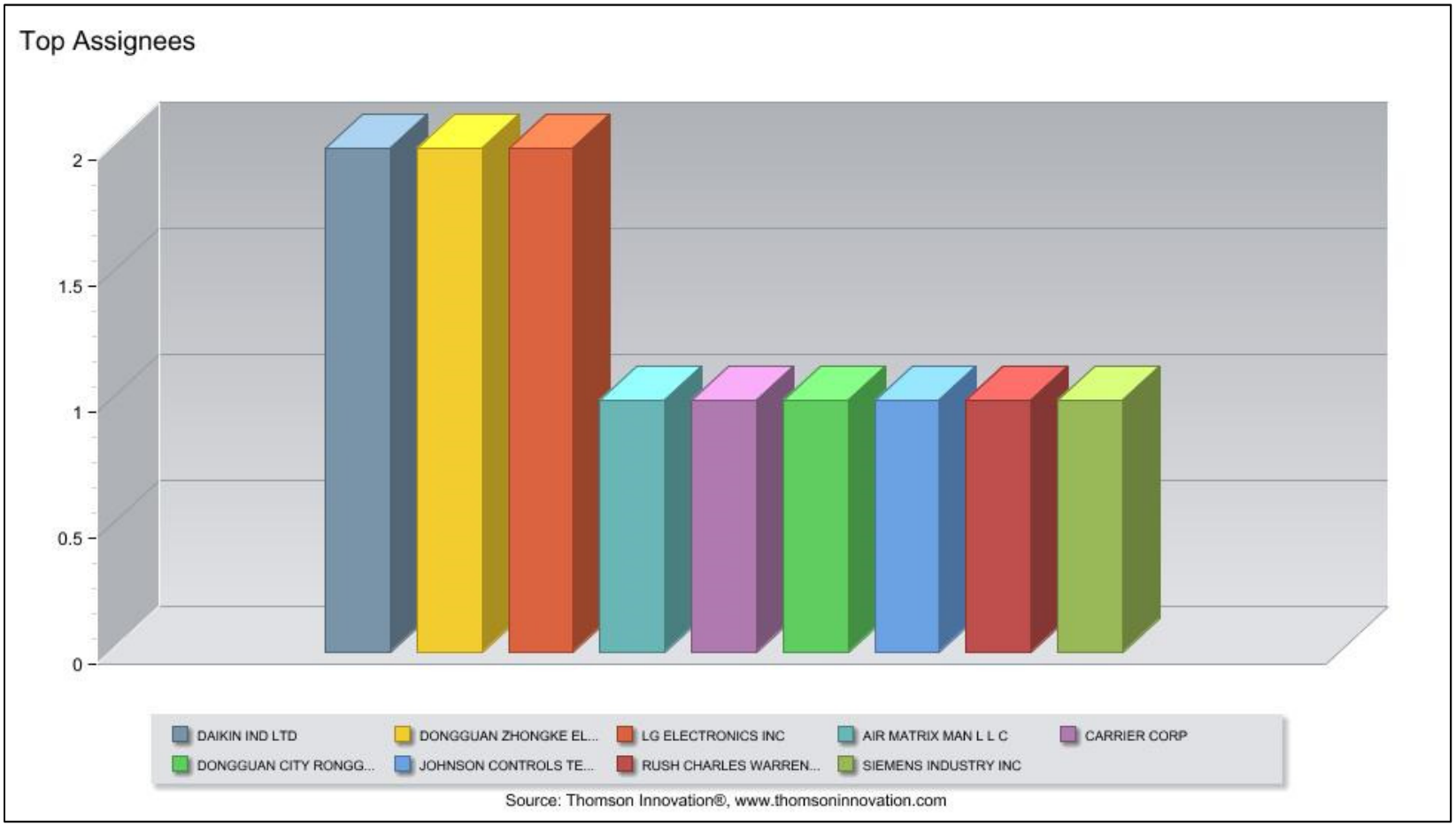
Patent search results were clustered based on DWPI Patent Families*. DWPI families are constructed based on a novelty principle.

Entire search results were manually reviewed by our subject matter experts to identifying documents relevant to with given technology area

Each Relevant document was reviewed to check whether there is any overlap with given technology

Patent Distribution by Assignee Name

Only 12 patents and published applications were identified which were specifically relevant to given technology. The exhibit below shows patent count-wise distribution of patent holders.



Source: Thomson Innovation

US9250002, Assignee: Carrier Corporation

(12) **United States Patent**
Wang et al.

(10) **Patent No.: US 9,250,002 B2**
(45) **Date of Patent: Feb. 2, 2016**

(54) **SYSTEM AND METHOD FOR CONTROLLING AN ABSORPTION CHILLER CONFIGURED TO SIMULTANEOUSLY PRODUCE COOLING AND HEATING**

(75) Inventors: **Jiachuan Wang**, Chaper Hill, NC (US); **Chaohong Cai**, Weatogue, CT (US); **Ahmad M. Mahmoud**, Bolton, CT (US); **Junqiang Fan**, Glastonbury, CT (US); **Richard L. Martin**, Cicero, NY (US); **John F. Boardman**, Manchester, CT (US); **Timothy C. Wagner**, East Hartford, CT (US)

(73) Assignee: **CARRIER CORPORATION**, Farmington, CT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 671 days.

(21) Appl. No.: **13/405,823**

(22) Filed: **Feb. 27, 2012**

(65) **Prior Publication Data**

US 2012/0216552 A1 Aug. 30, 2012

Related U.S. Application Data

(60) Provisional application No. 61/447,366, filed on Feb. 28, 2011.

(51) **Int. Cl.**
F25B 29/00 (2006.01)
F25B 49/04 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F25B 49/043*** (2013.01); ***F24D 3/18*** (2013.01); ***F24H 4/02*** (2013.01); ***F25B 29/006*** (2013.01); *F24D 2200/126* (2013.01); *Y02B 30/12* (2013.01)

(58) **Field of Classification Search**
CPC F24H 4/02; F24D 3/18; F24D 2200/126; F25B 29/006; F25B 49/043; Y02B 30/12
USPC ..... 62/103–105, 141, 146–148, 159; 236/1 C, 78 D; 700/44, 45
See application file for complete search history.

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(Continued)

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Primary Examiner — Marc Norman
Assistant Examiner — Paolo Gonzalez
(74) *Attorney, Agent, or Firm* — Cantor Colburn LLP

(57) **ABSTRACT**

A system for controlling an absorption chiller includes feedback control loops determining adjustments to system cooling and heating capacities and a controller for simultaneously adjusting positions of an energy input valve, a hot water valve, and a chilled water valve. The controller adjusts valves based on desired adjustments to system cooling and heating capacities and performance maps characterizing relationships between cooling capacity and heating capacities and valve positions. A method for controlling an absorption chiller includes the step of obtaining a performance map characterizing heat energy input to cooling and heating loops as functions of valve positions. To obtain the map, the hot water valve is held in a substantially constant position while the chilled water valve is modulated. Similarly, the hot water valve is modulated while the chilled water valve is held in a substantially constant position.

5 Claims, 3 Drawing Sheets

Use:
System for controlling an absorption chiller i.e. tri-generation system, for simultaneously cooling and heating to condition air of a building.

Advantage:
The absorption chiller is simultaneously controlled or operated in a heating mode and a cooling mode so as to simultaneously produce desired levels of the heating and cooling. The system controls the absorption chiller to meet priority cooling or heating, while maintaining chilled water and hot water outlet temperature and associated control valves automatically without violating chiller safe operating constraints in a stable manner. The system modulates a position of a chilled water valve so as to reduce a control error.

Novelty: The system has a feedback control loop determining desired adjustment to system heating capacity based on difference between desired heating capacity and realized heating capacity. A multiple-valve controller simultaneously adjusts an energy input valve position, a hot water valve position and a chilled water valve position based on desired adjustment to system cooling capacity and heating capacity and performance maps characterizing relationships between heat energy input to cooling and heat energy input to heating.

Source: Thomson Innovation

JP2013160397A, Assignee: Daikin Industries

Espacenet

Bibliographic data: JP2013160397 (A) — 2013-08-19

CHILLER CONTROL SYSTEM

Inventor(s):	KONDO YASUHIRO; NAGASHIMA TOSHIHIRO; UEDA TAKESHI ± (KONDO YASUHIRO, ; NAGASHIMA TOSHIHIRO, ; UEDA TAKESHI)
Applicant(s):	DAIKIN IND LTD ± (DAIKIN INDUSTRIES LTD)
Classification:	**- international:** ***F24F11/02*** **- cooperative:**
Application number:	JP20120020285 20120201 Global Dossier
Priority number(s):	JP20120020285 20120201

Abstract of JP2013160397 (A)

PROBLEM TO BE SOLVED: To lengthen a service life while securing a load following characteristic at start as the entire system.SOLUTION: A chiller control system (10) includes a family control unit (12) which allows one group having less operation time than the other groups to preferentially operate, from among first to third groups (Gr 1 to Gr 3) corresponding to one load, while first to third group control units (13 to 15) corresponding to the first to third groups (Gr 1 to Gr 3) which are operated with the family control unit (12) are so configured as to operate corresponding heat pump chillers (D1 to D4, D5, D6, D7, D8) simultaneously.

Use:

System for controlling chiller installed in rooftop of building.

Advantage:

The lifetime improvement of the chiller control system can be achieved effectively. The trackability of the load fluctuations at the time of starting the control system can be ensured.

Novelty:

The system has several control units (Gr1-Gr3) which are provided with a chiller (D1-D8). A unit control portion controls the chiller corresponding to each control unit. An integrated controller controls several control units corresponding to the load with little operation time over another control unit. The chiller of the control unit working by the integrated controller is controlled.

Source: Thomson Innovation

JP2011122812A, Assignee: Johnson Controls

Espacenet

Bibliographic data: JP2011122812 (A) — 2011-06-23

CONTROLLER AND METHOD FOR PROVIDING COMPUTERIZED GENERATION AND USE OF THREE-DIMENSIONAL SURGE MAP FOR CONTROL OF CHILLER

Inventor(s):	TURNEY ROBERT D; DREES KIRK H; LENHARDT BRETT M; CRANE CURTIS C ± (TURNEY ROBERT D, ; DREES KIRK H, ; LENHARDT BRETT M, ; CRANE CURTIS C)
Applicant(s):	JOHNSON CONTROLS TECH CO ± (JOHNSON CONTROLS TECHNOLOGY CO)
Classification:	**- international:** ***F25B1/053; F25B49/02*** **- cooperative:** **F25B1/053; F25B49/02**
Application number:	JP20100234435 20101019 Global Dossier
Priority number(s):	US20090253291P 20091020
Also published as:	EP2322877 (A2) EP2322877 (A3) US2011093133 (A1) US8726678 (B2) KR20110043504 (A) more

Abstract of JP2011122812 (A)

PROBLEM TO BE SOLVED: To provide a system and method for controlling a chiller to improve energy efficiency and preventing a surge condition. ;SOLUTION: This controller for the chiller includes processing electronics configured to detect a plurality of chiller surge events. The processing electronics calculate a point for each detected surge event in at least a three-dimensional coordinate system. The three-dimensional coordinate system describes at least three conditions of the chiller when the surge event is detected. The processing electronics are configured to calculate a surface map for the at least three-dimensional coordinate system by using the calculated points. The processing electronics are further configured to control at least one set point for the chiller by using the calculated surface map. ;COPYRIGHT: (C)2011,JPO&INPIT

Use:

Controller for chiller used in building management system.

Advantage:

The processing electronics control setpoint for the chiller using the surface map calculated for the three dimensional coordinate system, thus increasing the chiller efficiency by determining that a variable speed drive (VSD) is set to a lower frequency and avoiding generated surge point.

Novelty:

The controller has processing electronics that detect surge events to calculate a point for each detected event in a three dimensional coordinate system, which describes three conditions of a chiller (14) when the surge event is detected. A surface map for the three dimensional coordinate system is calculated. A setpoint for the chiller is controlled using the calculated surface map by the processing electronics. A surge region of the system is defined by the electronics, which conduct control actions to prevent current operating conditions of the chiller from reaching the surge region.

Source: Thomson Innovation

US8774978, Assignee: Siemens

United States Patent
Higgins et al.

(10) **Patent No.: US 8,774,978 B2**
(45) **Date of Patent: Jul. 8, 2014**

DEVICE AND METHOD FOR OPTIMIZATION OF CHILLED WATER PLANT SYSTEM OPERATION

Inventors: **Robert Higgins**, Henderson, NV (US); **Brendan McMasters**, Braintree, MA (US)

Assignee: **Siemens Industry, Inc.**, Buffalo Grove, IL (US)

Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 221 days.

Appl. No.: **13/149,563**

Filed: **May 31, 2011**

Prior Publication Data

US 2011/0301766 A1 Dec. 8, 2011

Related U.S. Application Data

Continuation-in-part of application No. 12/758,780, filed on Apr. 12, 2010, now Pat. No. 8,417,392, which is a continuation-in-part of application No. 12/507,806, filed on Jul. 23, 2009, now Pat. No. 8,275,483.

Int. Cl.

G05D 3/12	(2006.01)
G05D 5/00	(2006.01)
G05D 9/00	(2006.01)
G05D 11/00	(2006.01)
G05D 17/00	(2006.01)
G05D 7/00	(2006.01)

U.S. Cl.
USPC **700/295**; 700/282

Field of Classification Search
USPC 700/282, 295

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Primary Examiner — Mohammad Ali
Assistant Examiner — Ziaul Karim

(57) **ABSTRACT**

A demand flow device configured to interface with a chilled water plant controller to optimize performance of one or more chilled water plant components over a range of demand conditions is disclosed. The demand flow device includes a communication device configured to receive sensor data associated with the one or more chilled water plant components, wherein the sensor data measures operational variables of the chilled water plant. The demand flow device further includes a demand flow controller in communication with the communication device. The demand flow controller is configured to utilize the received sensor data to: determine an optimal pressure setpoint as a function of a desired chilled water delta T; control a chilled water flow rate through the one or more chiller water plant components as a function of the optimal pressure setpoint and the desired chilled water delta T; and adjust, via the chilled water plant controller, the optimal pressure setpoint, in response to one or more detected triggering events, to perform a critical zone reset of the desired chilled water delta T.

Use:

Demand flow device for use in a demand flow control system (claimed) to manage performance of a chilled water plant subsystem used to cool campuses, industrial complexes and commercial buildings.

Advantage:

The device increases the operating efficiency of chilled water plants and components, thus saving energy and cost. The device is environment-friendly. The device increases the life expectancy of the chilled water plants and components by operating the components at chilled water temperatures. The control of individual pumps of the device is resulted in synchronized operation of the chilled water plants, thus balancing flow rates in the chilled water plants, and hence significantly reducing or eliminating low delta T syndrome.

Source: Thomson Innovation

WO2016006872A1, Assignee: LG Electronics

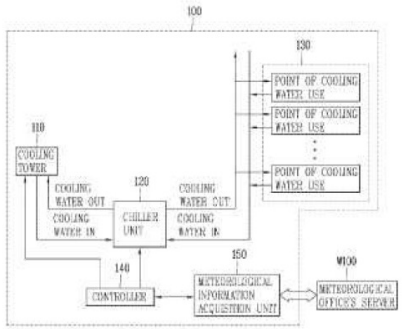
Bibliographic data: WO2016006872 (A1) — 2016-01-14

CHILLER

Inventor(s):	HAN CHANYOUNG [KR]; KIM KYEUNGJAE [KR]; SON JUNSEO [KR] ± (HAN, CHANYOUNG, ; KIM, KYEUNGJAE, ; SON, JUNSEO)
Applicant(s):	LG ELECTRONICS INC [KR] ± (LG ELECTRONICS INC)
Classification:	**- international:** ***F24F11/02; F24F11/053; F25B49/00; F28C1/00*** **- cooperative:** **F28C1/00**; **F28F27/003**
Application number:	WO2015KR06818 20150702 Global Dossier
Priority number(s):	KR20140085390 20140708
Also published as:	KR20160006046 (A)

Abstract of WO2016006872 (A1)

A chiller includes a cooling tower with a cooling fan that moves outside air to cooling water to cool the cooling water, a chiller unit that is connected to the cooling tower by a cooling water circulating channel to receive the cooling water from the cooling tower and connected to a point of chilled water use for air-conditioning the target area by a chilled water circulating channel to supply chilled water to the point of chilled water use at a given chilled water temperature, and a controller for determining the chilled water temperature based on external load information and internal load information.



Use:

Chiller e.g. water-cooled chiller and air-cooled chiller such as heat pump air-cooled chiller, for air-conditioning a target area e.g. building, shopping mall, floor space of building and floor space of shopping mall.

Advantage:

The chiller reduces energy waste from heat sources that consume lot of energy in the building through dynamic control of the chiller unit or cooling tower supply temperature depending on load using environmental variables leading to load changes as the chiller determines the chilled water temperature of the chiller unit based on the external load information and the internal load information, thus reducing building energy consumption. The chiller prevents abnormal operation of the chiller unit by avoidance and control of factors that cause abnormalities of chiller unit operation.

Source: Thomson Innovation

Patent Landscape Analysis - Key Findings

- Patent landscape analysis was conducted to understand patenting activity during last 20 years in given technology area. Patenting activity shows that R&D that is being carried out in this sector is being significantly converted for acquiring intellectual property protection.

- Patent search results were manually reviewed by our subject matter experts to identifying documents relevant to with given technology area. Only 12 patents/published application were found that were specifically relevant to given technology area. Detailed review of above documents shows that no direct technological overlap was noticed with OEM's patent and hence OEM has an unique solution in the market.

- Review of patent filings across different patent offices shows that The United States patent office witnessed highest patenting activity among major offices globally. This trend suggest that various multinational corporation consider USA as one of the key potential market and seeking to protect their intellectual property in USA. Japan, China and South Korean patent offices also witnessed patenting activity.

Technology Due-diligence

Title: Energy Management Control		Tech. ID number:		Inventors: Sridharan Raghavachari
IP LANDSCAPE		**MARKET ASSESSMENT**		
Patent life /disclosure date	9	Regulatory Risk Analysis	8	
Overlapping patents	8	Cost comparison to alternate means/tech. to achieve the goal	7	
Is the space crowded? No # of companies/labs	6	Addressable market size – based on current technology	8	
Growth opportunities - saturated or uncharted territory	8	Projected market size – subject to bridging of tech. gaps	6	
Uniqueness of the technology	9	Market location	7	
Climate Impact Score	NA	Development Cost Curve	8	
		Adoption Risks	6	
(Scoring Scale: 1-10)		Short investor return cycle	9	
Technology				
Technology Disruptiveness	6	Scalability	8	
Stage of development	9	Competing /alternate technologies	6	
Length of the innovation cycle	9	Relevant Commercial Half Life	8	
Prototype/ Preclinical Data	9	Client Score	NA	
Leveraging Existing Technology	NA	Variable Factor Score	NA	

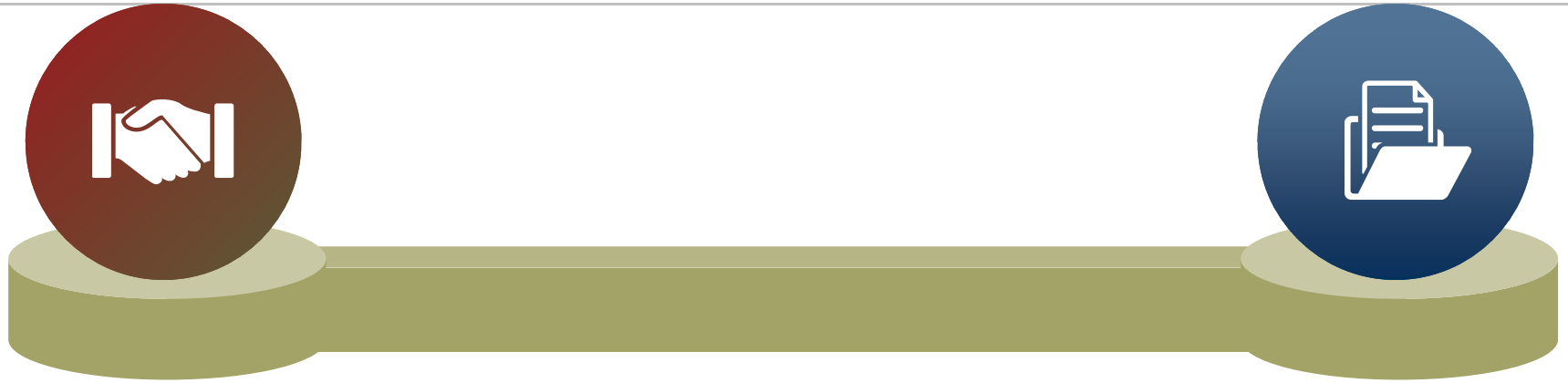
The technology was evaluated based on several criteria that are broadly classified as follows.

- Market-fit for the given technology
- Competitive patent landscape
- Technology Due-diligence

The scoring ranges from 0 to 10 with 0 being the least favorable and 10 as most favorable.

Valuation of OEM's Technology/IP and Business Model

Valuation of OEM's Technology / IP and Business Model



Business Model Valuation

Based on amount of cash flow generated by adopting various Business Contract Models specific to Energy Efficiency improvement

Technology / IP Valuation

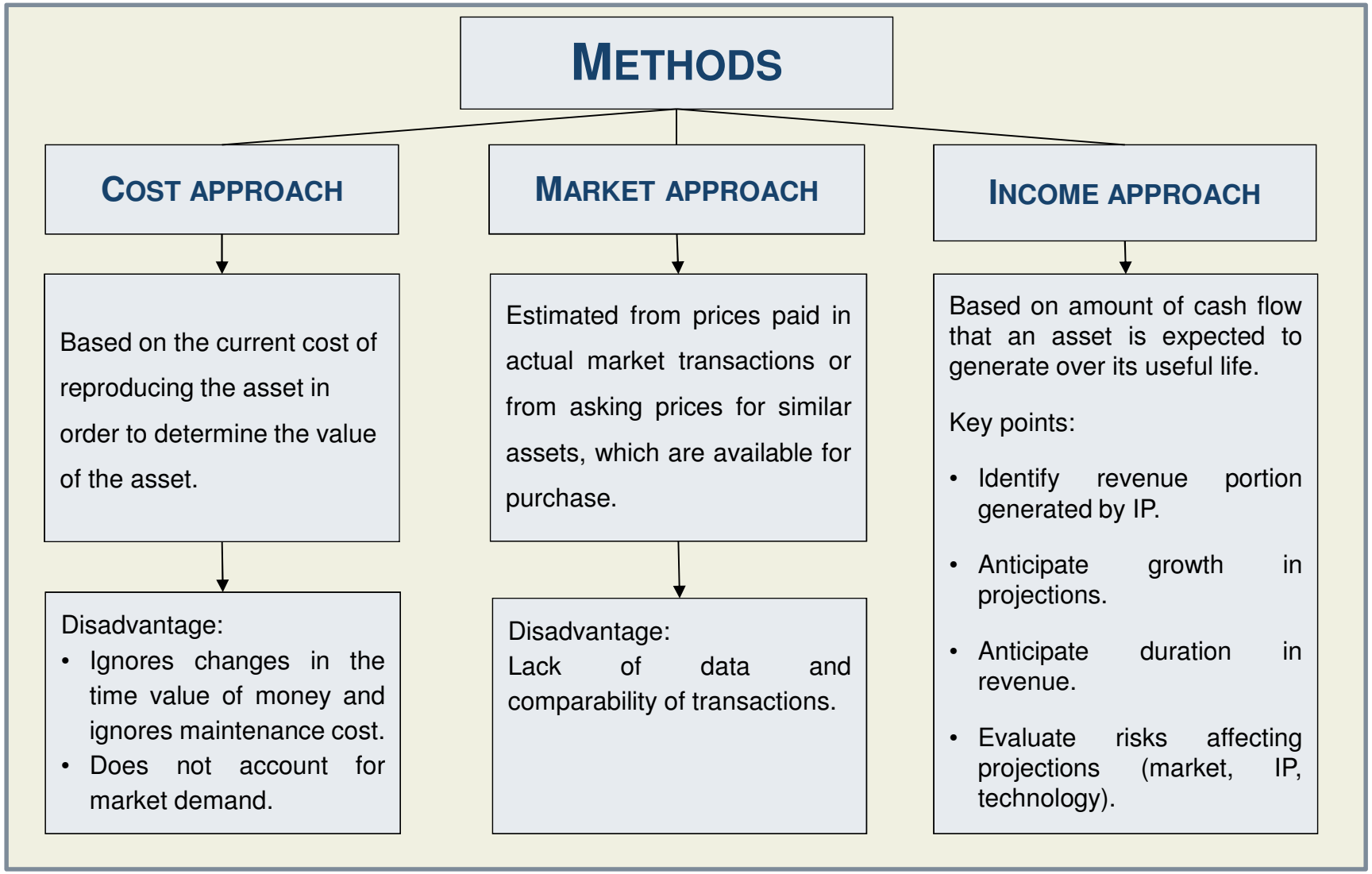
Based on royalty based cash flow that an asset is expected to generate over its useful life.

Scenario-wise Addressable Market

Royalties based Cash Flow

Total Risk Adjusted Net Present Value (rNPV)

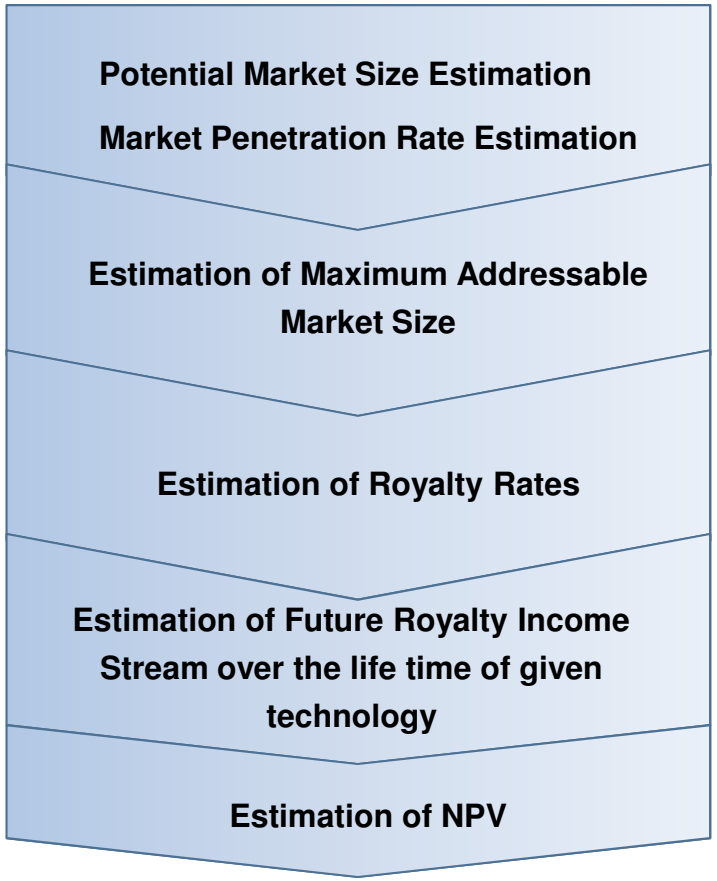
Methods of IP Valuation



IP Valuation - Methodology

- Frost and Sullivan team used income based approach for IP Valuation because this model allows flexibility to do valuation under different scenarios. Key aspects of this model are highlighted below.
- This model is based on estimation of royalty payments from which the company is relieved due to its ownership of the asset.
- Based on royalty rates, it computes future royalty income stream over the life cycle of given technology.
- After estimating future royalty income stream, a discount rate is applied to determine the Net Present Value (NPV) of the IP assets.
- Then, a risk adjustment factor is used as a multiplier on the NPV to arrive at the Risk Adjusted Net Present Value (rNPV).
- Risk adjustment factor is calculated based on several parameters such as company's patent portfolio volume and patent strength, competitors patent portfolio volume and patent strength, stage of development in IP life cycle etc.

IP Valuation Model – Key Steps



Risk Adjusted Net Present Value (rNPV)

IP Valuation - Key Data point and Assumptions

- Market size estimates and growth rates for above segments were sourced from Frost & Sullivan database.
- Market size estimation for HVAC Controls Specific to Chillers Segment was done based on data sourced from Frost & Sullivan database. This data is available on next slide.
- Market Penetration % is % of existing market to be substituted after introduction of products using OEM's technology. This is estimated based on several market, technology and IP assets related parameters.
- Maximum Addressable Market Size = Potential Market Size X Penetration Rate
- Royalty Rates were estimated based on historical review of comparable deals in the industry. Total Royalties are calculated by adding up royalty data from year 2018 to 2022.
- After estimating future royalty income stream, a discount rate is applied to determine the Discounted cash flow. No specific data for Chillers industry was available so average rates for the Energy and Environment industry were considered. Cost of Capital for Discounted Cash flow and Net Present Value Calculations: 9 % (Data Source: S&P Capital IQ)
- After estimating Net Present Value (NPV) of the IP assets, a risk adjustment factor is used as a multiplier on the NPV to arrive at the Risk Adjusted Net Present Value (rNPV).
- Here, Risk adjustment factor of 2/3 is considered based on completive patent landscape review.
- Several factors such as patent volume, patent strength, patent status (application/ grant), stage of development were considered to arrive at Risk adjustment factor. Data was sourced from unbiased third-party database Thomson Innovation.

Global Programmable HVAC Controls Market Specific to Chillers Segment

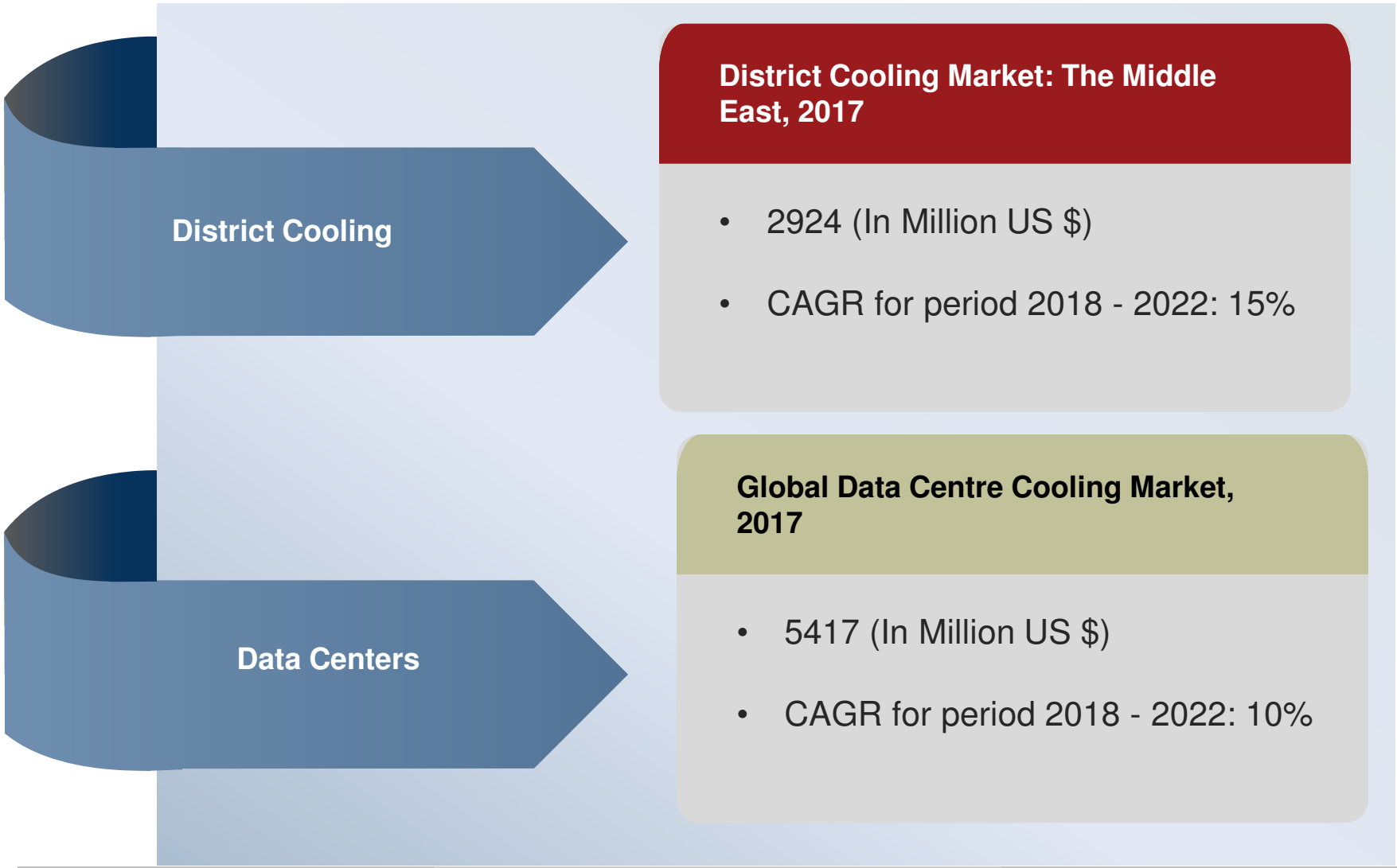
Programmable HVAC Controls Market For Chillers : Revenue Forecast, Global, 2015

Region	Revenues ($ Million)	(%) Share of Chillers in Total Market	Revenues for HVAC Controls Specific to Chillers ($ Million)	CAGR (2015 – 2022)
North America	4614.2	36	1661.1	5.3
Europe	3316.5	30	1061.3	4.4
APAC	3028.1	22	666.2	5.6
Rest of the World	3460.7	38	1315.0	4.7
Global	14419.38		4614.2	4.9

Revenue Forecast for HVAC Controls Specific to Chillers, Global, 2017 ($ Million): 5077

Note: All figures are rounded. Source: Frost & Sullivan analysis.

Market Size Data for District Cooling and Data Centers



Data Points Used for Business Model Valuation

Global Energy Saving Performance Contracting Market specific to HVAC and Building Automation

Global Energy Saving Performance Contracting Market specific to HVAC and Building Automation: Revenue Breakdown, Global, 2017

Region	Total Revenues ($ Million)	(%) Share of HVAC and Building Automation Market	Revenues for Global Energy Saving and Performance Contracting Market specific to HVAC and Building Automation ($ Million)
North America	7597.3	-	-
Europe	6015.2	-	-
APAC	3403.1	-	-
Rest of the World	4253.9	-	-
Global	21269.5	31	6593.6

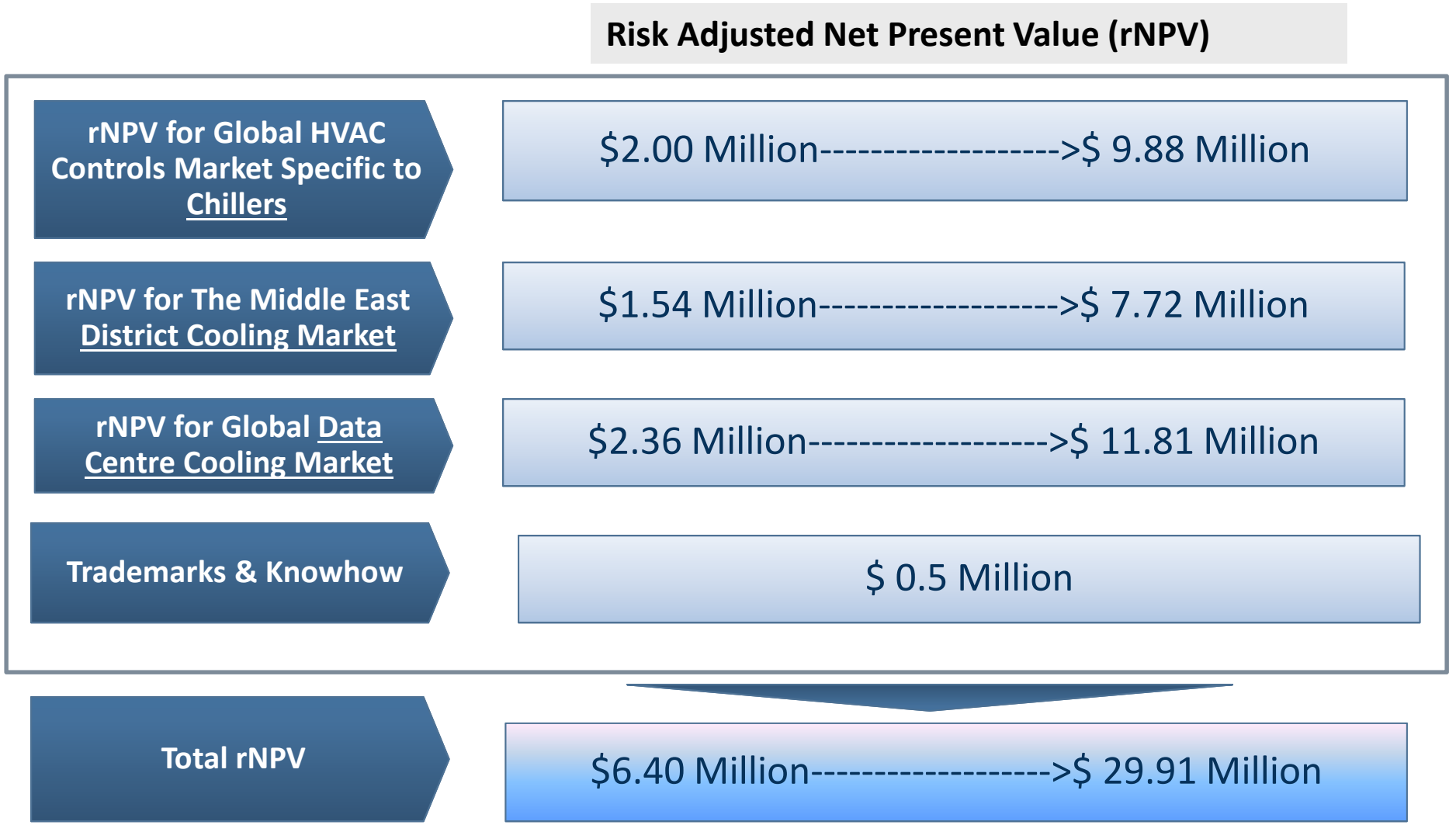
Note: All figures are rounded. Source: Frost & Sullivan analysis.

Scenario-wise Risk Adjusted Net Present Value (rNPV) for Global HVAC Controls Market Specific to Chillers

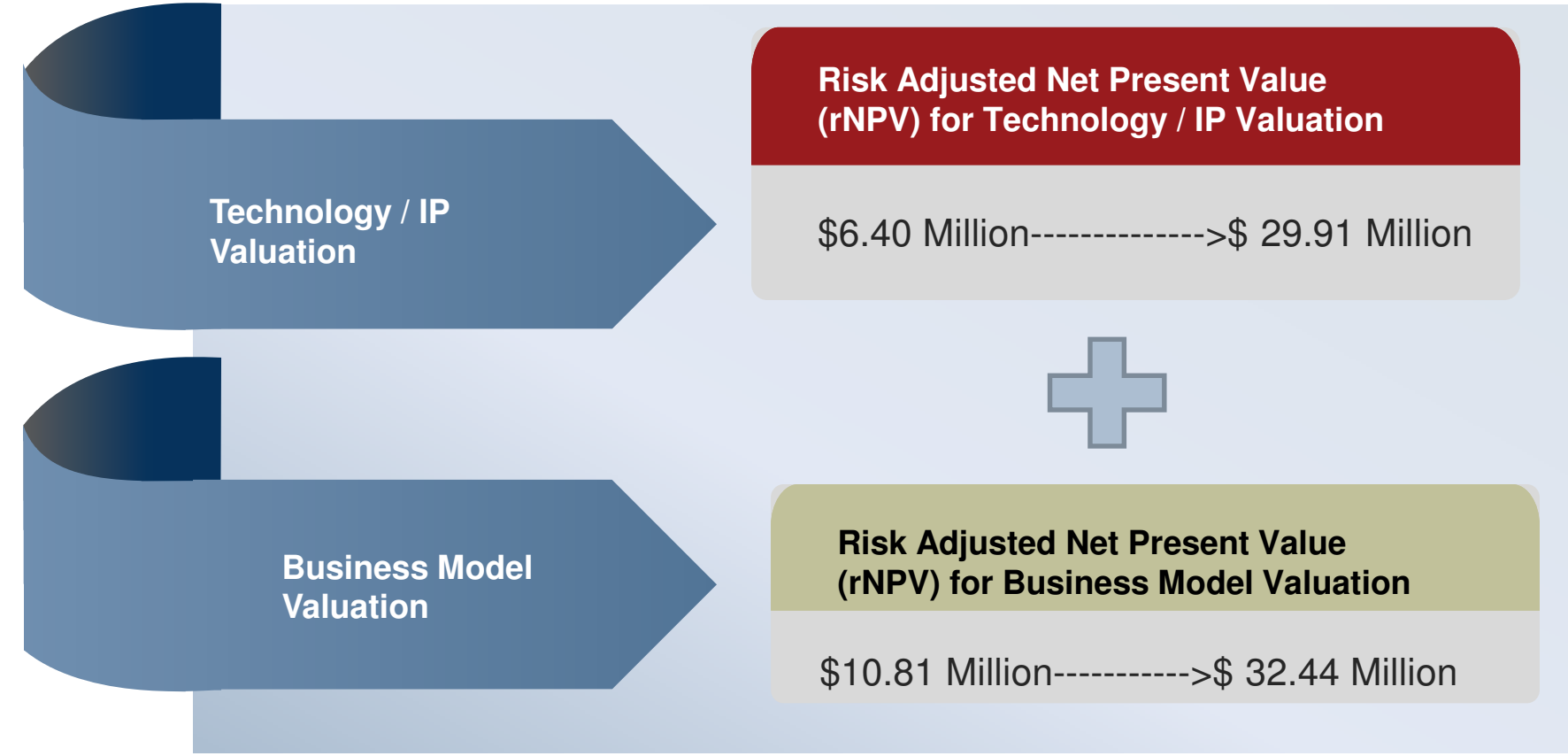
	Scenario 1 Geographical Coverage – Global	Scenario 2 Geographical Coverage – North America	Scenario 3 Geographical Coverage – Middle East
rNPV Value at 5 % Royalty Rate	$ 9.88 Million	$ 3.46 Million	$ 1.86 Million
rNPV Value at 3 % Royalty Rate	$ 5.99 Million	$ 2.07 Million	$ 1.11 Million
rNPV Value at 1 % Royalty Rate	$ 2.00 Million	$ 0.69 Million	$ 0.37 Million

- Risk Adjusted Net Present Value (rNPV) of OEM's IP assets are calculated based on a mathematical model developed by Frost and Sullivan. rNPV was calculated under three different scenarios. These scenarios were considered based on number of countries to be penetrated and level of penetration during the life cycle of given technology.
- For Royalties and rNPV estimation, we have made assumption that lifecycle of OEM's technology would be about 5 years. Therefore, calculations were made using 5 years time frame (2018- 2022)
- Trademarks and knowhow are estimated to be worth 0.5 Million USD.

OEM's Technology / IP Value Range (Market-wise)



Total Risk Adjusted Net Present Value (rNPV)



Total rNPV	$17.21 Million----------->$ 62.35 Million

THANK YOU