Microcontrollers: The Enabling Technology Behind Smart Grid Applications

Energy Efficiency and Technology Conference

Renesas Electronics America Inc.
Tim Dry, Consumer and Industrial Business Unit

Date: 5/06/10 Rev. 0.02
Agenda

- Who we are
- Smart Grid
- Solutions
- Smart House
Renesas Electronics - Who we are

April 1st, 2010

**The World’s 3rd largest Semiconductor supplier**

### Worldwide Semiconductor Suppliers: CY2009 Revenue Ranking

<table>
<thead>
<tr>
<th>Rank</th>
<th>Supplier</th>
<th>2009 Revenue ($M)</th>
<th>2009 Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intel</td>
<td>33,253</td>
<td>14.6%</td>
</tr>
<tr>
<td>2</td>
<td>Samsung Electronics</td>
<td>17,686</td>
<td>7.7%</td>
</tr>
<tr>
<td>3</td>
<td>Toshiba</td>
<td>9,604</td>
<td>4.2%</td>
</tr>
<tr>
<td>4</td>
<td>Texas Instruments</td>
<td>9,142</td>
<td>4.0%</td>
</tr>
<tr>
<td>5</td>
<td>STMicroelectronics</td>
<td>8,510</td>
<td>3.7%</td>
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<tr>
<td>6</td>
<td>Qualcomm</td>
<td>6,409</td>
<td>2.8%</td>
</tr>
<tr>
<td>7</td>
<td>Hynix Semiconductor</td>
<td>6,035</td>
<td>2.6%</td>
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<tr>
<td>8</td>
<td>Renesas Technology</td>
<td>5,670</td>
<td>2.5%</td>
</tr>
<tr>
<td>9</td>
<td>AMD</td>
<td>5,157</td>
<td>2.3%</td>
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<tr>
<td>10</td>
<td>Infineon Technologies</td>
<td>4,682</td>
<td>2.1%</td>
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<tr>
<td>11</td>
<td>NEC Electronics</td>
<td>4,542</td>
<td>2.0%</td>
</tr>
<tr>
<td>12</td>
<td>Broadcom</td>
<td>4,317</td>
<td>1.9%</td>
</tr>
</tbody>
</table>

**Source:** Gartner "Market Share: Total Semiconductors, Worldwide, 2009" 24 March 2010
Primary segments and solution focus

- Microcontrollers (MCUs)
  - World’s No. 1 market share
    - Energy-saving home appliances
    - Automotive Green cars

- Customers
  - Smart Grid solutions
  - Industrial/Factory Automation
  - Mobile devices
  - Consumer AV/PC

- System LSIs (SoCs/ASICs)
  - Advanced and proven technologies

- Analog & Power Devices
  - An extensive, high-quality lineup

- Advanced R&D
- Design development platform environment
- Wide-ranging manufacturing technologies
## MCU Supplier Ranking

### Worldwide MCU Ranking by Revenue ($M)

<table>
<thead>
<tr>
<th>CY2008 Rank</th>
<th>CY2009 Rank</th>
<th>Company</th>
<th>CY2009 Revenue</th>
<th>CY2009 Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Renesas Technology</td>
<td>1,982</td>
<td>18%</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>NEC Electronics</td>
<td>1,292</td>
<td>12%</td>
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<tr>
<td>3</td>
<td>3</td>
<td>Freescale Semiconductor</td>
<td>1,052</td>
<td>10%</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Samsung Electronics</td>
<td>849</td>
<td>8%</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Microchip Technology</td>
<td>684</td>
<td>6%</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>Texas Instruments</td>
<td>644</td>
<td>6%</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>Infineon Technologies (incl. Qimonda)</td>
<td>610</td>
<td>6%</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>STMicroelectronics</td>
<td>605</td>
<td>6%</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>Fujitsu Microelectronics</td>
<td>561</td>
<td>5%</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>NXP</td>
<td>431</td>
<td>4%</td>
</tr>
</tbody>
</table>

### U.S. MCU Ranking by Revenue ($M)

<table>
<thead>
<tr>
<th>CY2008 Rank</th>
<th>CY2009 Rank</th>
<th>Company</th>
<th>CY2009 Revenue</th>
<th>CY2009 Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Freescale Semiconductor</td>
<td>324</td>
<td>23%</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Renesas Technology</td>
<td>185</td>
<td>13%</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Texas Instruments</td>
<td>185</td>
<td>13%</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
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<td>171</td>
<td>12%</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>NEC Electronics</td>
<td>101</td>
<td>7%</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>STMicroelectronics</td>
<td>97</td>
<td>7%</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>Atmel</td>
<td>76</td>
<td>5%</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>Infineon Technologies (incl. Qimonda)</td>
<td>58</td>
<td>4%</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>Cypress Semiconductor</td>
<td>49</td>
<td>4%</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>NXP</td>
<td>37</td>
<td>3%</td>
</tr>
</tbody>
</table>

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**Source:** Gartner Semiconductor Market Share, March 2010

**MCU Type (W/W)**
- 8-bit: #1 (20%)
- 16-bit: #1 (36%)
- 32-bit: #1 (38%)

**Renesas Electronics Corporation**
- 30% Share (Worldwide)
- 20% Share (U.S.)
Renesas Electronics Advantages

**RESPONSIVE**
To customer requirements

**INNOVATIVE**
Technologies and a broad product and solutions portfolio

**WORLD-CLASS**
Quality—Flexible Supply

**TRUSTWORTHY**
Extensive sales and support network
Smart Grid
Smart Grid – Past Motivators

- Automated meter reading (AMR)
  - Reduced cost
  - Consumption feedback – Time of Use (ToU)
  - Anti-theft
  - Detection of leaks (water/gas)

- Automated remote disconnect
  - Two way communications
  - Automated Meter Infrastructure (AMI)
  - Reduced cost
  - Safety
  - Demand response..
Smart Grid – Motivation today

- Demand Response: No more brown-outs or black-outs
  - Balancing demand peaks with generation capacity
  - Encourage conservation and energy efficiency
- Reduces capital expenditure for new generation and infrastructure
- $3.4 Billion ARRA US Government funding
Smart Grid – Clean, Green & Future Motivations

- Reduced CO2 by clean technology including storage (PEV)
- Integration of CO2 neutral “distributed-renewable-energy” like wind, solar, biomass
- New services and business models not yet thought of!!

Electric Vehicles
US Smart Grid

Regulation/Deregulation
• Energy Policy Act 1992 => Wholesale markets
• $3.4Bn Smart grid Energy Incentives US ARRA
• Standards for interoperability

Utilities
• 3,000+ utilities, 200 serve 80% US
• 1000 utilities generate power
• Largest 3 by Revenue:
  • Florida Power & Light
  • Southern California Edison
  • Pacific Gas & Electric

5% improvement in grid efficiency equal to eliminating green house emissions from 53 Mn cars ~ US Department of Energy

$20Bn Revenue 2010, $100Bn by 2030 – Morgan Stanley

• US nationwide demand to grow by 30% 2030

NIST Smart Grid framework

Markets
Operations
Service Provider

Bulk Generation
Transmission
Distribution

Home Area Network HAN
Connecting Appliances, HVAC, Lighting to Meter

Distributed power
Solar market $30Bn 2008 to $81Bn by 2018 - Clean Edge

Neighbor Area Network (NAN)

250Mn Smart Meters WW by 2015 – Pike Research
PG+E installing 12,000 everyday
Goal 10Mn installed by 2012

Neighborhood Area Network (NAN)

250Mn Smart Meters WW by 2015 – Pike Research
PG+E installing 12,000 everyday
Goal 10Mn installed by 2012

3.4Mn ZigBee Nodes 2010 growing to 8.2Mn 2014 - WRTS

40~50 companies in Silicon Valley including start-ups and tech giants focusing on Smart Grid technologies.
Smart Grid/AMI/AMR Projects Worldwide
Smart Grid Challenges

- Consumer acceptance
  - Privacy
  - Accuracy
  - Conflicts of interest
    - Proposition 16

- Technical and legislation
  - Standards for interoperability
  - Security
  - Costs

- Future Proofing
  - Flexibility
  - Scalability
Microcontrollers Make the Grid Smart

- Safe, clean and efficient power generation
  - Control and monitoring
  - Lab equipment
  - Cost Savings

- Secure and reliable transmission
  - Transformer analysis
  - Power line monitoring
  - Self healing network
  - Network side time synchronization
  - Power quality and machine disturbance

- Smart Meter
  - Accurate and frequent measurement
  - Two way communications from Utilities to house
  - Communication to appliances in the house
  - Communication to In House (Energy) Display
Microcontrollers Enable Smart House Applications

Home Area Network (HAN)
ZigBee, PLC and/or Wifi Communication

- Lighting ASSPs
- SoCs
- Low-power MCUs
- LCD MCUs
- Inverter MCUs
- Meter ASSP or SoCs

Geared to support next-generation smart house applications, Renesas Solutions portfolio offers a broad and deep range of devices enabling energy management, security, environmental control and more. Enabling true intelligence.

Neighborhood Area Network (NAN)
- 900MHz RF
- 2.4GHz RF
- WiMAX RF
- Cell Phone RF
- Power Line Carrier

Electric Vehicles

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Smart Meter evaluation platform

Note: SW1 for display function; SW2 for Harmonics injection in test mode; SW3 for reset
Smart Meters – Networking requirements increasing

- A Flexible platform design is desired

- One system architecture could separate the metrology and the communication
  - Metrology MCU supports measurement, which is more constant
  - Communication MCU supports growing communication and advanced features, requiring:
    - 32Bit 50MIPs MCU
    - 1MByte Flash and 64K SRAM memory and growing
    - Good EMI/EMC/EMS performance
    - Low power
Smart Meters – Scalable Platforms

- The flexible architecture enables one PCB design for several tiers of meters, reducing design cost
  - Low-end – metrology MCU + communication MCU with low memory
  - High-end – metrology MCU + communication MCU with high memory

- Requires a scalable family of microcontrollers

- Requires different memory configuration with the same footprint
Scalable Memory with Same Footprint

32-bit V850ES/JJ3 has the same package with a different memory configuration (384 KB to 1 MB)

Many of our MCUs have the same scalable choices
Security - The Big Bad Wolf

- Any network is target for attack

- Theft
  - Revenue loss
  - Service Level Agreement
  - Cloning

- Malicious attack
  - Denial of services
  - Increased costs of operations
  - Unfair competition
  - License and brand protection
  - Credibility with partners and customers
  - Device effectiveness

  - NIST, NSA Smart Grid Interoperability Panel (SGIP)
  - Cyber Security Coordination Task Group (CSCTG)
From simple ID to strong authentication

Small groups

Larger society

Networked society

Today

Name

Name + ID

Authentication

Strong M2M authentication

BOARD ID

M2M AUTHENTICATION
Board ID use examples

**Single Board device**
- Main MCU authenticates the Board ID device

**Remote device**
- Server authenticates the remote devices via a network

**Main unit and Peripheral**
- Mutual Authentication with Board ID 2.0

**Server**
- Network

**MCU**
- Board ID / Security chip
Avnet Value Added Services (VAS)

Customer data / Product ID

Secure manufacturing site

Secure chip, locked; unusable without user keys

Key / X509 cert gen. specific to customer with unique user keys; auditable records

Secure programming of user keys: unique per chip; only a firm certified by Renesas can program; auditable records

Secure logistics; distribution service

Customer or customer approved CM

Avnet VAS Avail. Now!

Avnet provides a One-Stop-Shop for Board ID Product and Services
Microcontrollers Enable Smart House Applications

Home Area Network (HAN) ZigBee, PLC and/or Wifi Communication

- Lighting ASSPs
- SoCs
- Inverter MCUs
- MOSFETs and SoCs
- LCD MCUs
- Smart Appliances
- WiFi Router
- Solar Panel
- Electric Meter
- Motor Control ASSPs
- HVAC
- Thermostat
- Gas Meter
- Meter ASSP or SoCs
- Low-power MCUs
- Electric Vehicles

Neighborhood Area Network (NAN)
- 900MHz RF
- 2.4GHz RF
- WiMAX RF
- Cell Phone RF
- Power Line Carrier
In-Home Display block diagram

- Control (keys, touch)
- Wireless comms
  - ZigBee/802.15.4
  - Or WiFi
- Wired comms
- Battery

MCU

Energy Home Display Unit

- Electricity Now: 072.10
- Cost: 252
- Gas Now: 10000
- Cost: 48
- Carbon Now: 005.19

Time: 00:07:54
Temperature: 22

Low 8bit battery power to high 32bit with Media

Power Line Carrier, Ethernet
In Home Display (IHD) – Mid~high solutions

SH7724
- GUI, animation, Digital Audio, HD Video

SH7264
- QVGA -> SXGA (HD)
- Video CODEC in HW,
- JPEG CODEC in HW
- USB Host, SDMC,
- I2S, SPDIF
- MMU support Linux, QNX, Adobe Flash lite

DD-LCD
- QVGA/HVGA/VGA
- GUI, Raw video overlay
- Blending
- USB Host, SDMC
- I2S, SPDIF

System Cost
- $7.00
- $12.00
- $20.00

Performance and Features
- 1000 DMP
- 250 DMP
- 50 DMP
In-home Energy Display – wireless battery powered

- Requires low-power design
- Support for wireless communication (ZigBee Pro)
- Needs a real-time calendar to track
- Support for segmented LCD

Diagram:
- Powerline
- Total Energy Usage
- Pricing Info
- ZigBee
- Big-screen TV
- Low-power LCD/TFT MCU
- MCU with embedded 802.15.4 radio
- Wireless Energy Display
Low-power, In-home Energy Display

- To achieve low power, we can observe the following
  - Radio might be on periodically to detect signal
  - Only when a user interacts, the in-home energy display does additional processing and shows data

- To maximize battery life, the MCU should have
  - Independent on/off control of radio and MCU
  - Different operating frequencies
    - Signal detection – runs at low frequency
    - Processing – runs at high frequency

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU on; radio Tx (0dBm)</td>
<td>18.9 mA @ 4 MHz, 22.3 mA @ 16 MHz</td>
</tr>
<tr>
<td>CPU on; radio Rx</td>
<td>17.4 mA @ 4 MHz, 20.8 mA @ 16 MHz</td>
</tr>
<tr>
<td>CPU run; radio off</td>
<td>3 mA @ 10 MHz</td>
</tr>
<tr>
<td>CPU STOP; RTC on; radio off</td>
<td>1.1 µA @ 3V</td>
</tr>
<tr>
<td>CPU STOP; radio off</td>
<td>0.47 µA @ 3V</td>
</tr>
</tbody>
</table>
Low-power, In-home Energy Display

- In-home energy display might only need to wake up every 15 minutes to record the energy usage of the past 15 minutes.
- A typical MCU with a timer needs to wake up the MCU every half second to update the second, minute, hour, etc. in memory.
- A dedicated real-time calendar (RTC) has embedded second, minute, hour, etc. registers to track time and eliminates waking up the MCU.
- Fewer wake ups = less power = longer battery life.

**Comparison Chart:**

<table>
<thead>
<tr>
<th></th>
<th>LCD MCU w/ simple timer</th>
<th>LCD MCU w/ RTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 min</td>
<td>15 min</td>
<td></td>
</tr>
<tr>
<td>MCU wakes up</td>
<td></td>
<td>MCU wakes up 1800 times</td>
</tr>
<tr>
<td>for processing</td>
<td></td>
<td>to update real-time in memory</td>
</tr>
<tr>
<td>+ time stamping</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Microcontrollers Enable Smart House Applications

Home Area Network (HAN)
ZigBee, PLC and/or Wifi Communication

- Lighting ASSPs
- SoCs
- Inverter MCUs
- MOSFETs and SoCs
- Smart Appliances
- HVAC
- Thermostat
- Gas Meter
- Electric Meter
- Meter ASSP or SoCs
- LCD MCUs
- Low-power MCUs
- TV

Motor Control ASSPs

Electric Vehicles

Neighborhood Area Network (NAN)
900MHz RF
2.4GHz RF
WiMAX RF
Cell Phone RF
Power Line Carrier
Individual Appliance Energy Consumption

- **Energy measurement MCU**
  - Dedicated analog front-end to measure energy
  - Real-time calendar to track time and put time stamp
  - Flash memory to store data

- **Communication MCU**
  - wireless ZigBee
  - more naturally, powerline communication
Energy measurement/Metrology 78K0/Lx3-M

- 24-bit ΔΣ ADC
- With Phase Adjustment
- Fault detection (2-wire only)

**Power Calculation Block**
- Active Power Cal.
- Reactive Power Cal.
- Apparent/Amp-hour Cal.

**Power Management Block**
- Zero-Cross/Timeout detection (2ch)
- Peak Detection (1ch)
- SAG Detection (2ch)
- Period/Freq. Measurement (1ch)

**Digital Frequency Conversion**
- CF-pin

To LCD MCU
Smart Appliances – energy efficient

- Additional intelligence required so that cycles complete safely
  - Washer not stopped in mid-cycle – damage clothing
  - Dish washer dry cycle not stopped – mold hazard

- Advanced motor control MCU for energy-efficient motor control
  - Dedicated peripherals to support advanced motor drive
  - Variable speed drive that efficiently maximizes output power
  - Multiple modes of operation with different levels of energy consumption
Microcontrollers Enable Smart House Applications

- **Lighting ASSPs**
- **SoCs**
- **Inverter MCUs**

**Home Area Network (HAN)**
- **ZigBee, PLC and/or Wifi Communication**
  - TV
  - Smart Appliances
  - HVAC
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  - Gas Meter
  - Electric Meter
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**Low-power MCUs**

**LCD MCUs**

**Motor Control ASSPs**

**Neighborhood Area Network (NAN)**
- 900MHz RF
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**Electric Vehicles**
Energy-efficient LED Lights

- LEDs are more energy efficient than incandescent and CFL lights
  - Incandescent light produces 20 lumens per watt
  - LED produces 200 lumens per watt
  - Fluorescent light produces 100 lumens per watt

- The challenges for LED lighting
  - Department of Energy requires LED lights to be dimmable
  - Dimmers are analog but driving LED uses digital PWM
  - Different analog dimmers have different characteristics
  - For global market, input universal voltage ranges from 87-277 volts

- The flexibility of LED microcontrollers overcome these challenges
  - Embedded special hardware to simplify driving of LEDs
  - Programmability of MCUs is adaptive to the different design criteria
Using LED MCUs to Support TRIAC Dimmer

- Run different software to support other dimmers and different PFC controls
Office/Factory LED Lighting

- Home lighting might not be the biggest energy hog
- But lighting in larger scale offices and factories is
- Using LED lights increases energy efficiency
- Networking LED lights eliminates energy waste
Networked LED Lighting in Offices

- LED MCU has the processing power to form a network and process “command and control” with sensors/controls

- Networked lighting could reduce energy waste
  - Occupancy and ambient light sensing
  - Occupant-controlled dimming
  - Multi-area control
Microcontrollers Enable Smart House Applications

- **Lighting ASSPs**
- **SoCs**
- **Inverter MCUs**
- **Solar Panel**
- **Low-power MCUs**
- **LCD MCUs**
- **MOSFETs and SoCs**
- **Home Area Network (HAN)**
  - ZigBee, PLC and/or Wifi Communication
  - **Neighborhood Area Network (NAN)**
    - 900MHz RF
    - 2.4GHz RF
    - WiMAX RF
    - Cell Phone RF
    - Power Line Carrier

- **Smart Appliances**
- **Motor Control ASSPs**
- **HVAC**
- **Thermostat**
- **Gas Meter**
- **Electric Meter**
- **Electric Vehicles**
Solar Panel – DC to AC Inversion

- The DC voltage generated by the solar panel or stored in the battery has to be converted to AC.
V850E/Ix4 DC to AC Inversion Solution
Measuring Solar Energy

- “Net Metering” put solar energy back to the grid if “grid tied”
- It would be good to measure how much energy is generated before sending it back

![Diagram showing solar panel, energy meter, ZigBee communication, and wireless energy display.]
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Renesas Smart Home Demo
Smart Home

- Clear plastic model house
  - 41.5” x 37.5”
  - 2-bedrooms
  - Living-room
  - Kitchen
  - Dining Room
  - Roof top

- Applications solved:
  - Climate Control
  - Lighting
  - Metering
Smart Home – Managing energy costs

- Employing Microcontroller (MCU) solutions to make a home:
  - Intelligent
  - Comfortable
  - Energy efficient

- Solutions include:
  - Metering
  - Power inverter controls (motor and solar)
  - LCD display
  - LED lighting
  - ZigBee/IEEE802.15.4 RF
  - Power Line Communications (PLC)
Smart Home - Components

Furnace control unit blows out warm air through the ducts.

LED street light
Via PLC

Smart meter connects the house to the grid.

In-Home Display shows energy consumption and HMI

PC Brain controls the house.

Solar panels contribute back onto the grid.

Thermostat regulates temperature by the duct opening

LED lighting can be turned on, off or dimmed.

Solar panels contribute back onto the grid.
Smart Home Management Software

- Main Menu

![Smart Home Application Platform]

- Climate Control
- Lighting Control
- Utility Meters
- System Info
Smart Home Management Software

- Lighting Control Menu
Smart Home Management Software

- Lighting Control Sub-Menu

![Living Room and Lighting Control Sub-Menu](image)
Smart Home Management Software

- Energy Consumption Info Menu

Graph showing energy consumption from 8:00AM to 8:00PM with peak at 15.6kW at 6:03PM. The cost is $0.12/kWh.
Renesas Microcontrollers and Microprocessor families
Summary

■ Smart grid and Smart Energy promise many benefits to the consumer, utilities and the planet

■ Application of technology enables the smart grid

■ Most applications will require a microcontroller based solution to make grid smart

■ Renesas Electronics has developed MCU solutions, several already successfully deployed in the grid applications shown

■ Renesas Electronics is ideally positioned to be your partner in your smart energy projects