



A Domain-Specific MBSE Approach for the Smart Grid

Christian Neureiter

Josef Ressel Center for User-Centric Smart Grid Privacy, Security and Control

Hi, I'm Christian...



Christian Neureiter



- ▶ **Salzburg University of Applied Sciences**
 - ▶ Teaching: Information and System Management
 - ▶ Research: Domain-Specific MBSE
 - ▶ www.en-trust.at
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- ▶ **Successfactory Systems Engineering**
 - ▶ Training, Consulting & Coaching
 - ▶ www.successfactory.cc
 - ▶ neureiter@successfactory.cc

Background



▶ Energy Turnaround: Integration of renewable energies

- ▶ Distributed Energy Resources (DER) with volatile injection behavior
 - ▶ Bidirectional energy flows influence grid stability
- ▶ Smart Grid
 - ▶ Management of bidirectional energy flows
 - ▶ Paradigm shift: „Load follows generation“
 - ▶ Integration of massive ICT infrastructure

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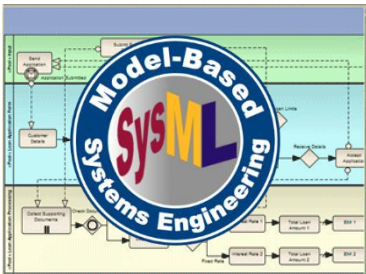
▶ Challenge: Develop of a robust and dependable system architecture

- ▶ Critical infrastructure → extense dependability requirements
- ▶ System-of-Systems (SoS) → high complexity
- ▶ Numerous stakeholders → different disciplines and domains involved

Interdisciplinary Development

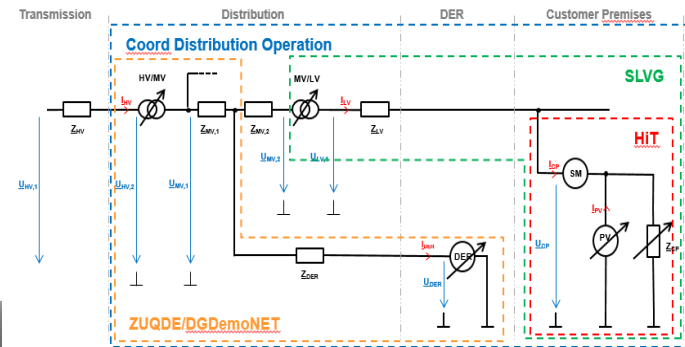


Hi, I'm Christian. I have great models to develop your Smart Grid!



So, how can we handle all this ICT related complexity?

No, this is Software stuff. THIS is, how a model should look like!



How to develop complex, interdisciplinary systems
together?

How to build a house?



Architecture Description

Architecture Development

Basic Views

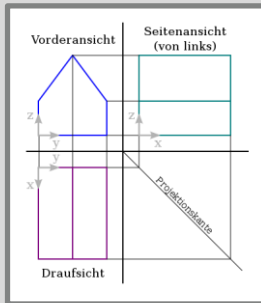
Architecture Models

Stakeholder Concerns

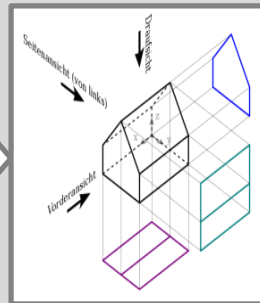
Reference Architecture

Architectural Solution

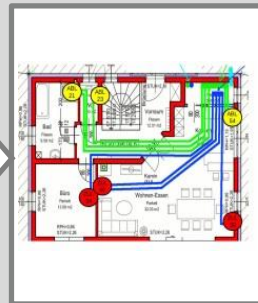
Building



Common Understanding



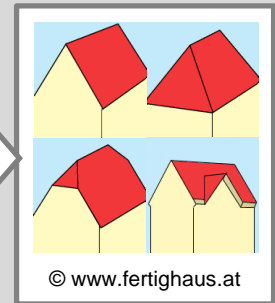
CAD Tools



Plumber, Electrician, Owner,...



„Blueprint“



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My individual house

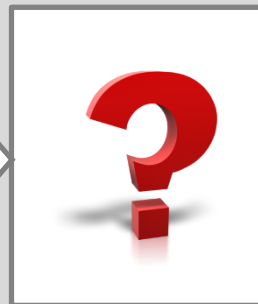
Smart Grid



Relevant Aspects ?



Modeling Tool ?



Concerns ?



Reference Architecture ?



Solutions ???

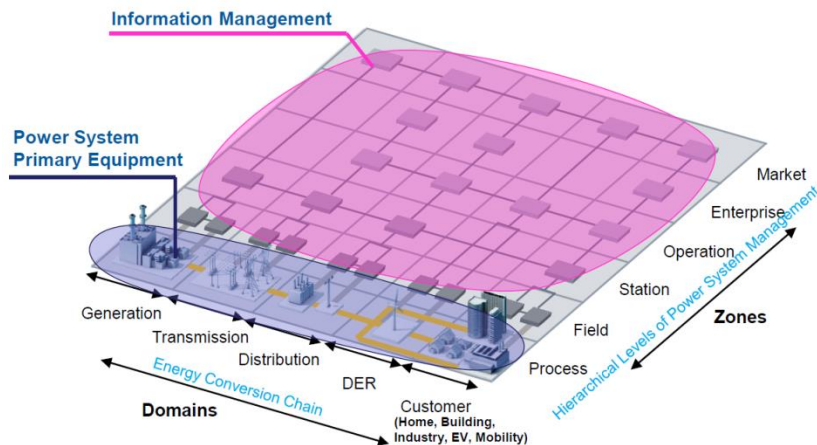
Smart Grid Architecture Model (SGAM)



▸ Proposed 2012 by CEN/CENELEC/ETSI

1. SGAM-Plane: problem decomposition

- Domains: energy conversion chain
- Zones: Automation pyramid



Smart Grid Architecture Model (SGAM)

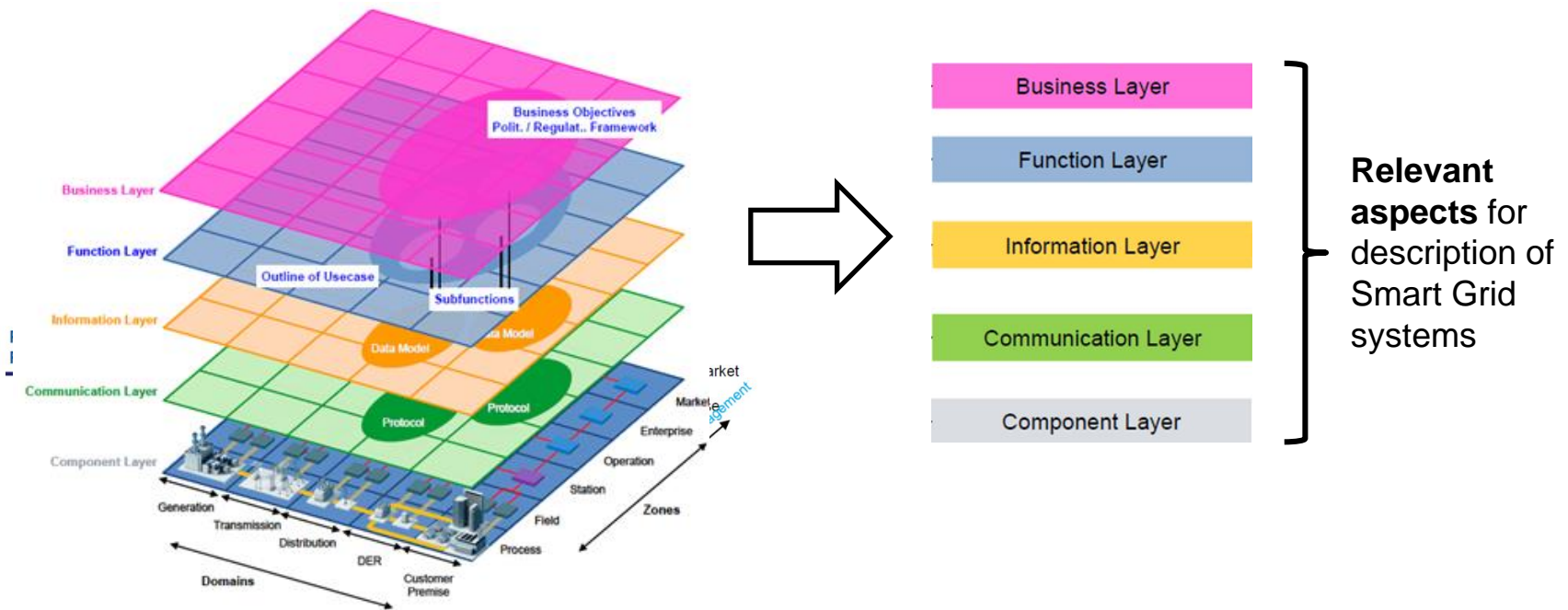


Proposed 2012 by CEN/CENELEC/ETSI

1. SGAM-Plane: problem decomposition

- Domains: energy conversion chain
- Zones: Automation pyramid

2. Interoperability on different layers („SGAM Layers“)



How to build a house?



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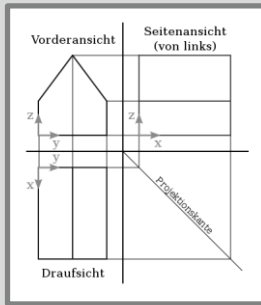
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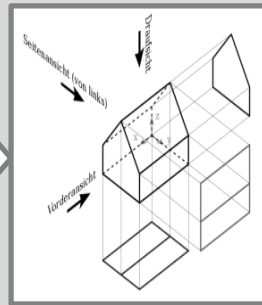
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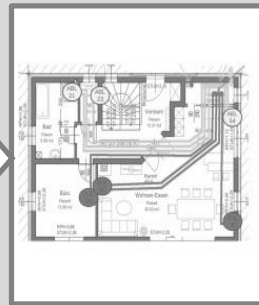
Architectural Solution



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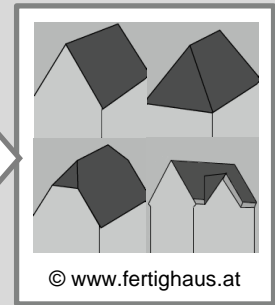
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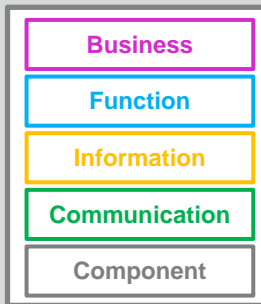
„Blueprint“



My individual house

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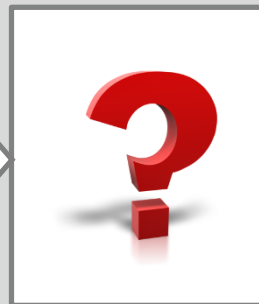
Smart Grid



Functional and architectural aspects



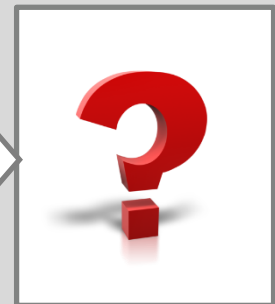
Modeling Tool ?



Concerns ?



Reference Architecture ?



Solutions ???

Modeling the Smart Grid



▸ **Modeling the Smart Grid**

1. Development paradigm
2. Domain Specific Modeling Language (DSL)

Modeling the Smart Grid

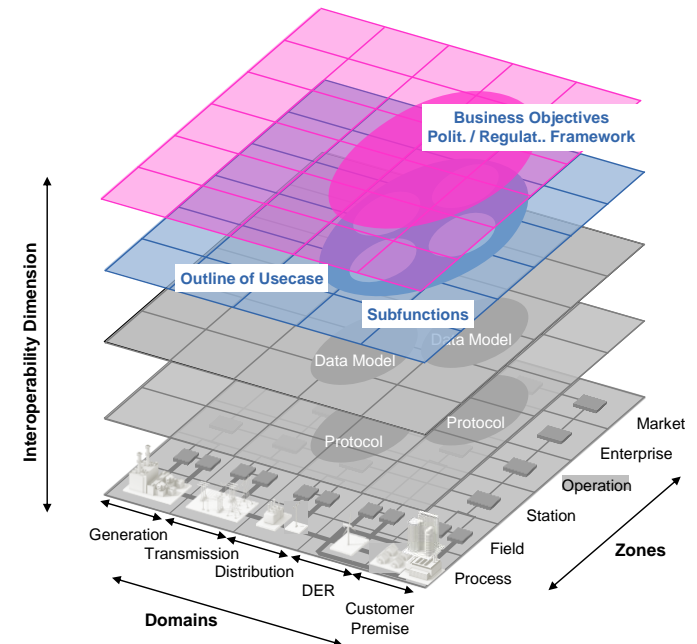


▸ Modeling the Smart Grid

1. Development paradigm
2. Domain Specific Modeling Language (DSL)

▸ Model Driven Architecture (MDA)

1. **Functionality („What?“)**
 - 1. Business Layer
 - 2. Function Layer
- } System Analysis



Modeling the Smart Grid



► Modeling the Smart Grid

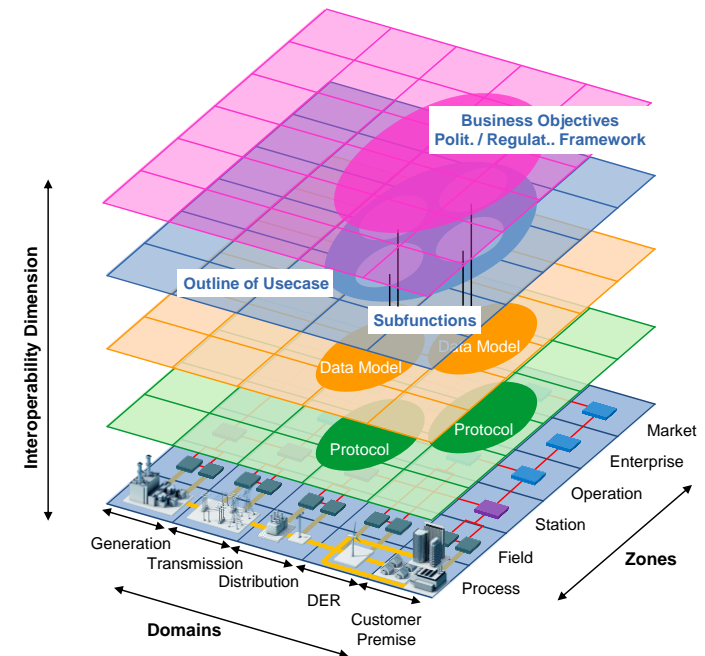
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► Model Driven Architecture (MDA)

1. **Functionality („What?“)**
 - 1. Business Layer
 - 2. Function Layer

System Analysis
2. **Technology („How?“)**
 - 1. Information Layer
 - 2. Communication Layer
 - 3. Component Layer

System Architecture



Modeling the Smart Grid



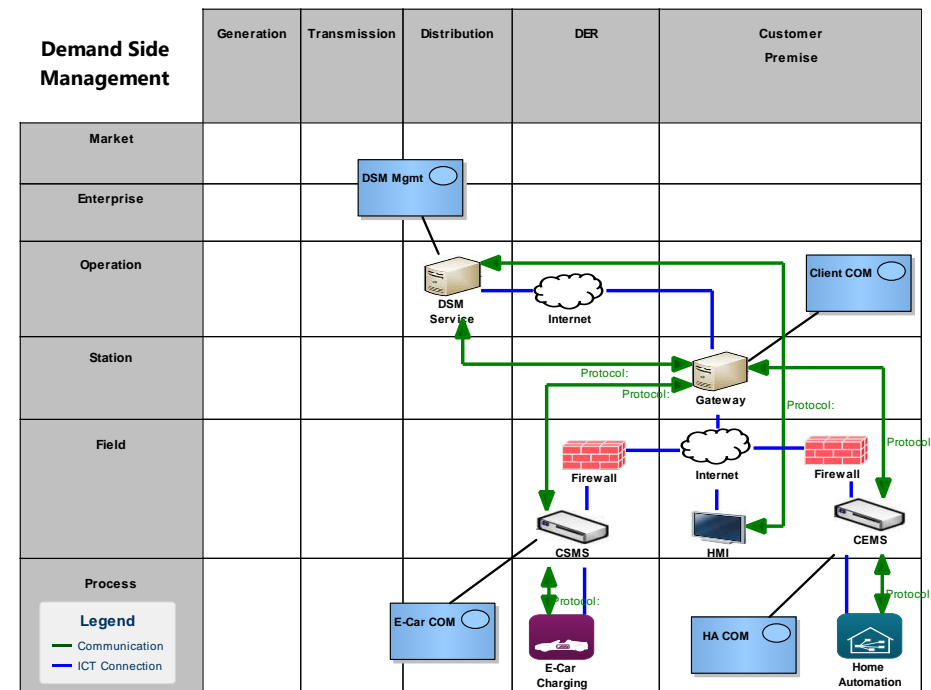
► Modeling the Smart Grid

1. Development paradigm

2. Domain Specific Modeling Language (DSL)

► The „SGAM Toolbox“

- Domain Specific Language (DSL)
- Extension for *Enterprise Architect*
- Layer-by-Layer development
 - „In the stakeholder’s language“



Modeling the Smart Grid

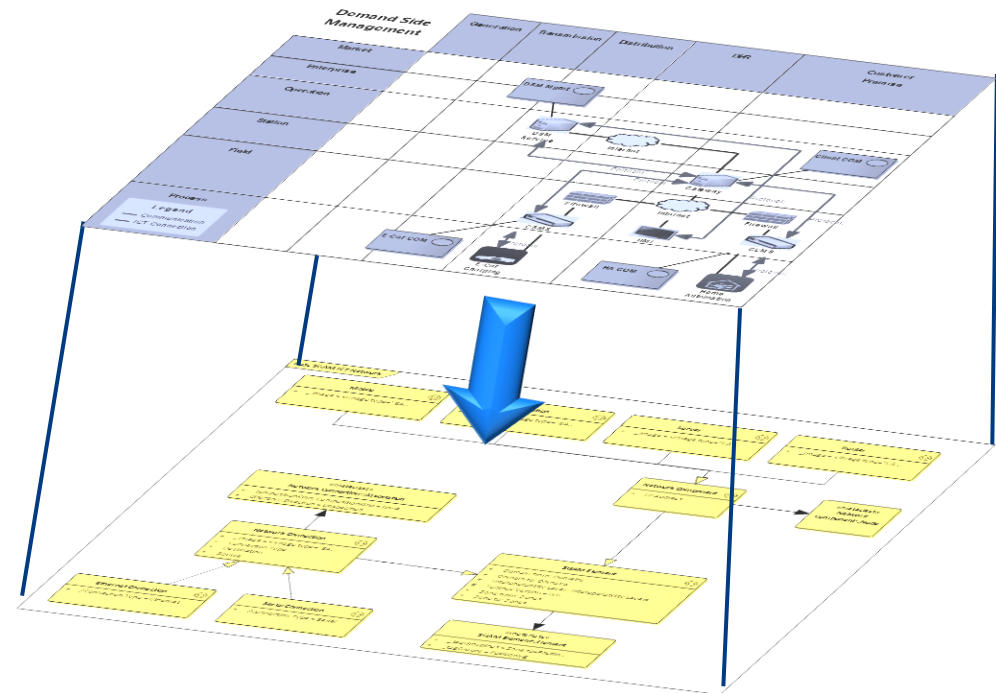


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- Under the hood: UML Profile



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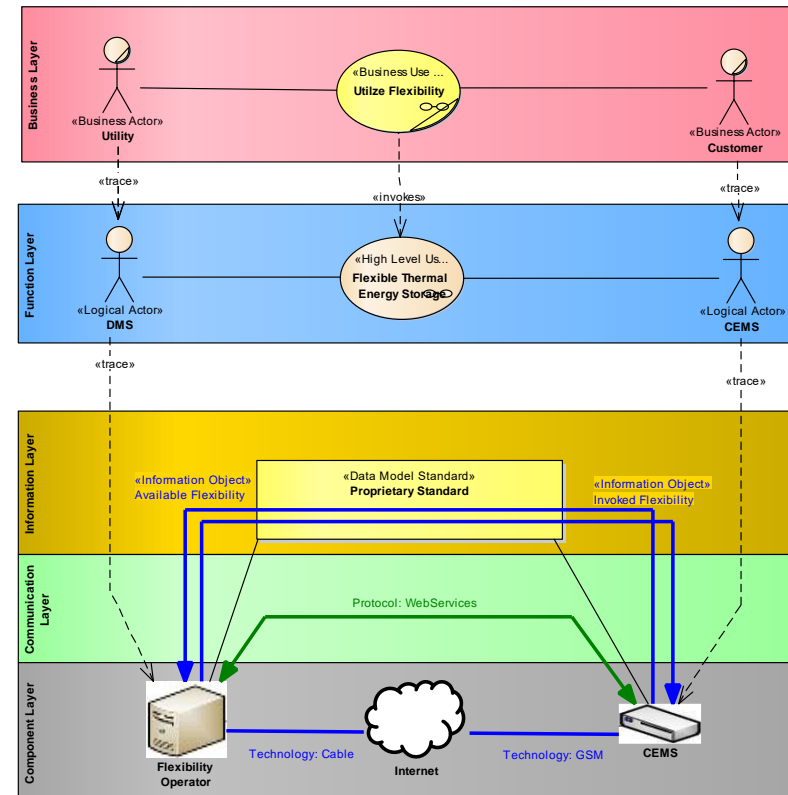
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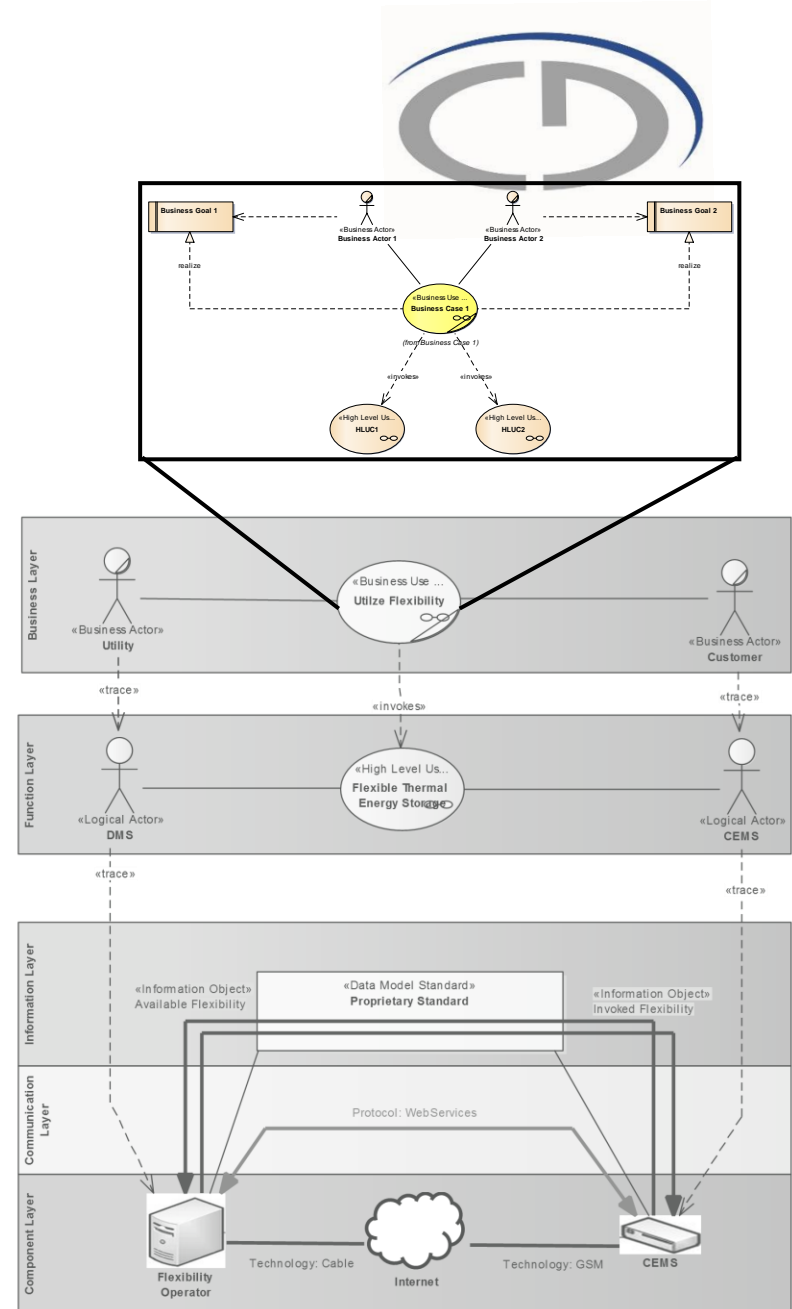
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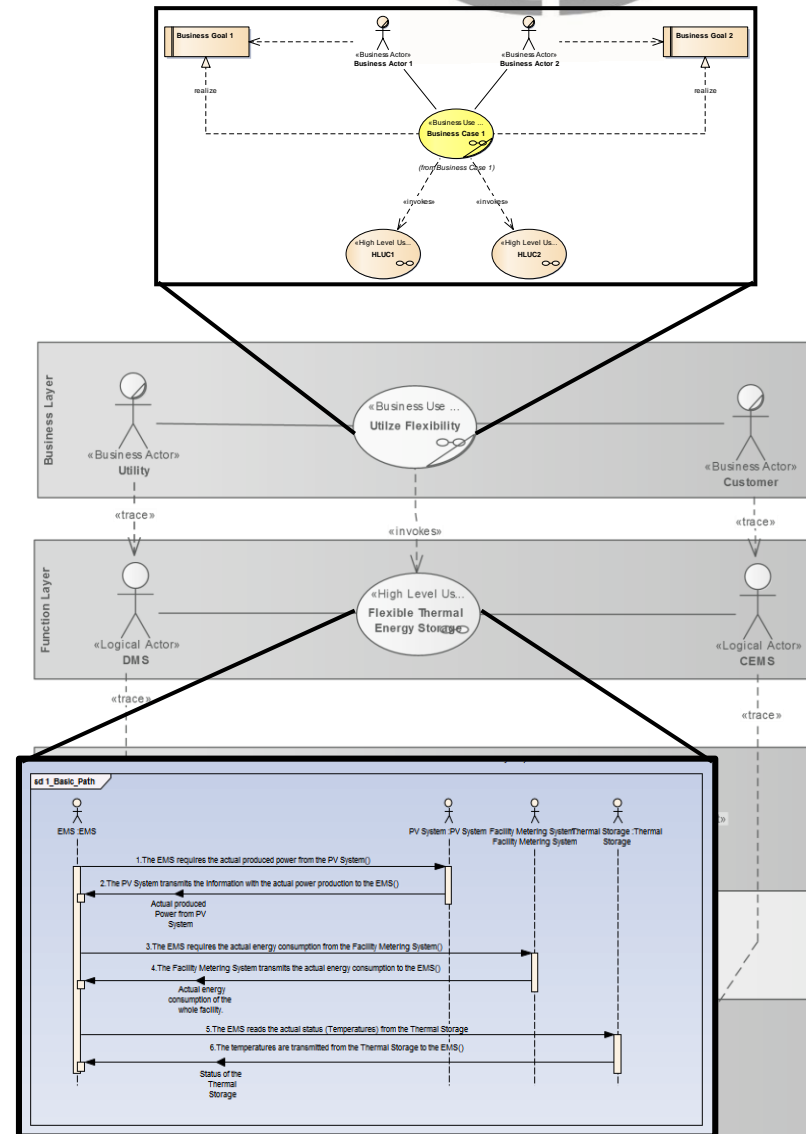
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- Under the hood: UML Profile
- **Publicly available**
 - www.en-trust.at → Downloads
 - Video-Tutorials on youtube



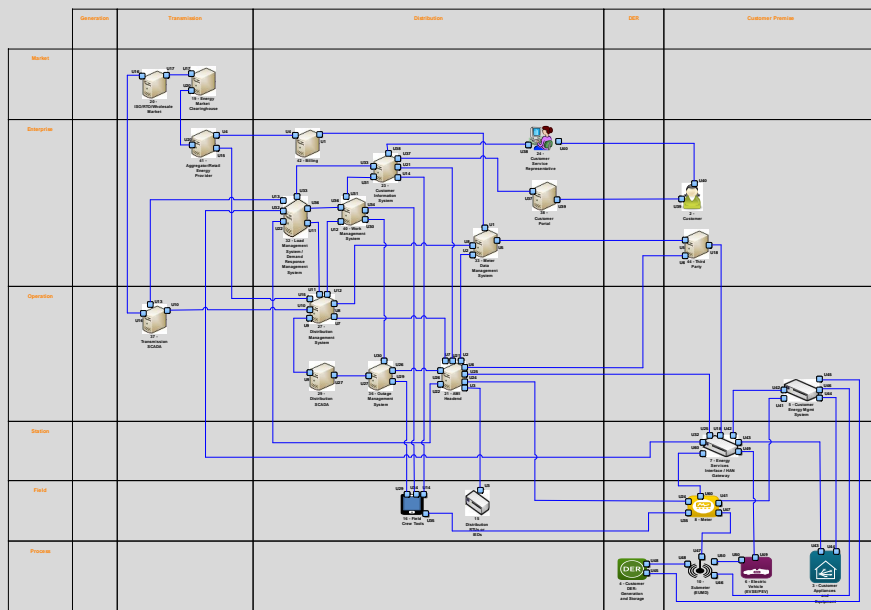
Stakeholder Concerns → Model Views



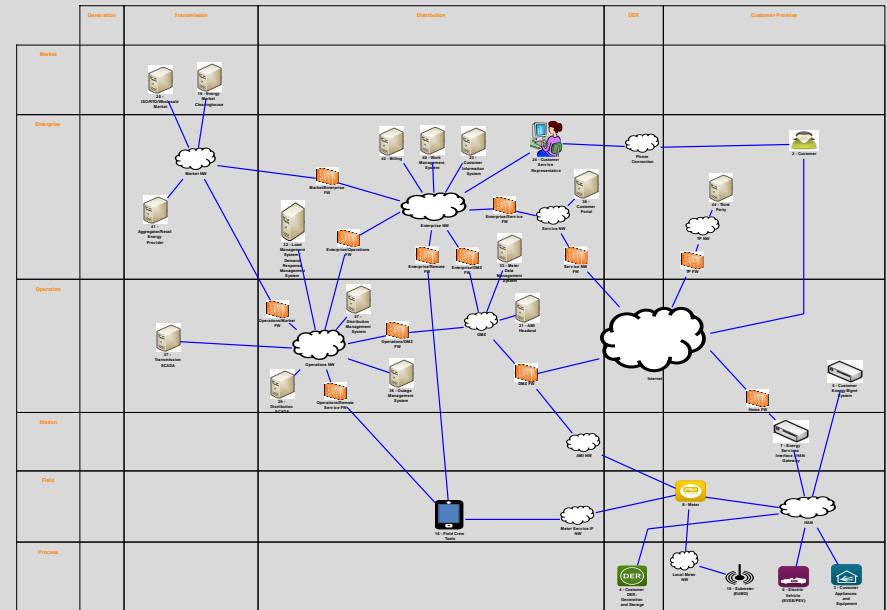
▸ Subject of investigation

- Example on „Component Layer“: Security, Network Segments

Interfaces and Security Requirements



ICT Network Topology



How to build a house?



Architecture Description

Architecture Development

Basic Views

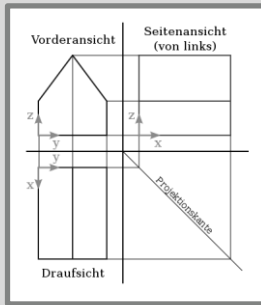
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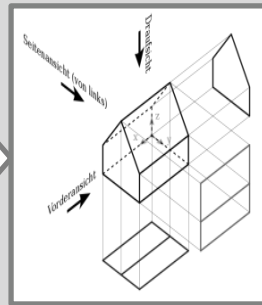
Reference Architecture

Architectural Solution

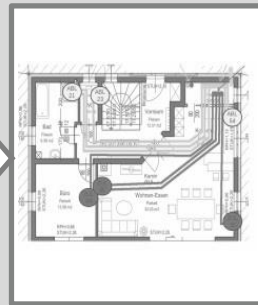
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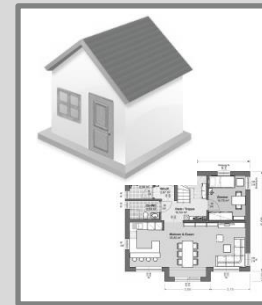
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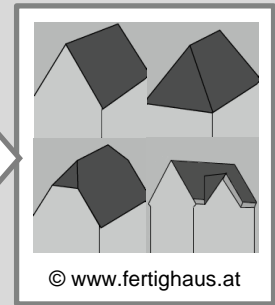
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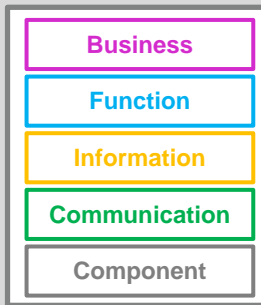
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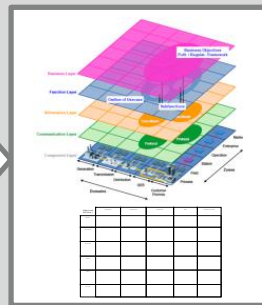
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My individual house

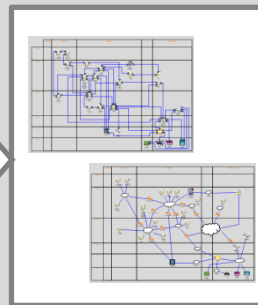
Smart Grid



Functional and architectural aspects



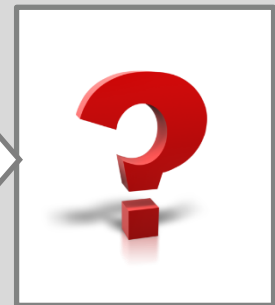
SGAM-Toolbox



Concerns & Views



Reference Architecture ?



Solutions ???

Reference Architecture

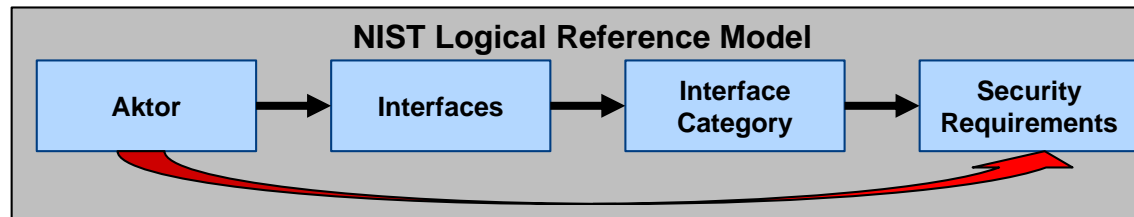
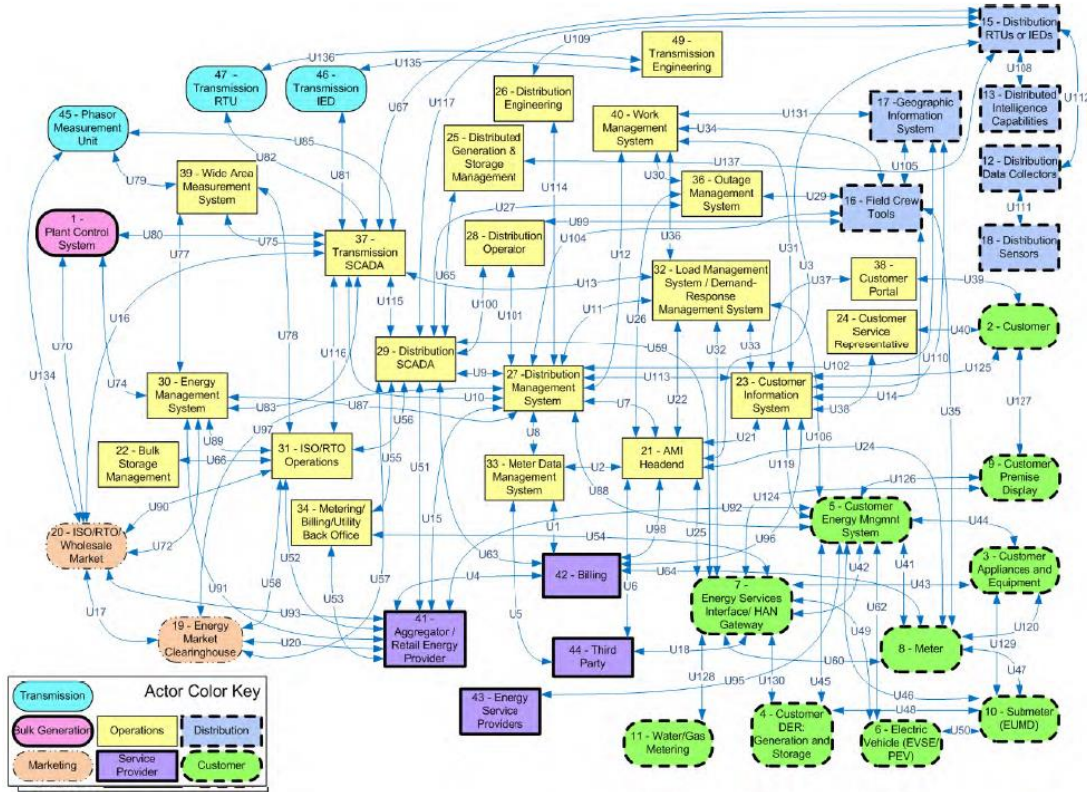


ENTSO-E Role Model

- Business Layer

NIST IR 7628 Guidelines for Smart Grid Cyber Security

- Use Case Collection
- Logical Reference Model
- ~ 46 Actors
- ~ 140 Interfaces
- 22 Interface Categories
- Security Requirements
 - ~200 High Level RQ



Reference Architecture



▶ ENTSO-E Role Model

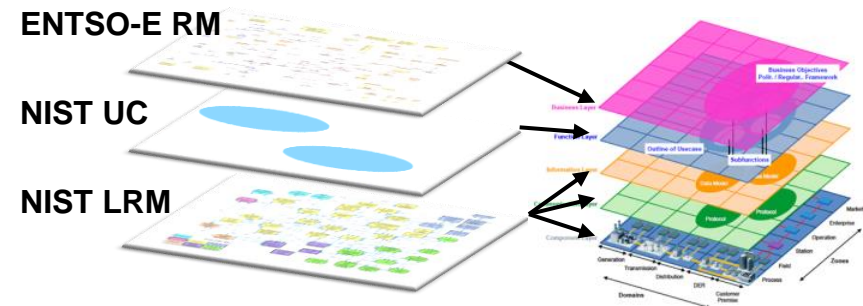
- ▶ Business Layer

▶ NIST IR 7628 Guidelines for Smart Grid Cyber Security

- ▶ Use Case Collection
- ▶ → Logical Reference Model
- ▶ ~ 46 Actors
- ▶ ~ 140 Interfaces
- ▶ → 22 Interface Categories
- ▶ → Security Requirements
 - ▶ ~200 High Level RQ

▶ Integration with SGAM

- ▶ Same origin!
 - ▶ NIST Domain Model
 - ▶ Mapping basically possible
 - ▶ Still, some issues exist...

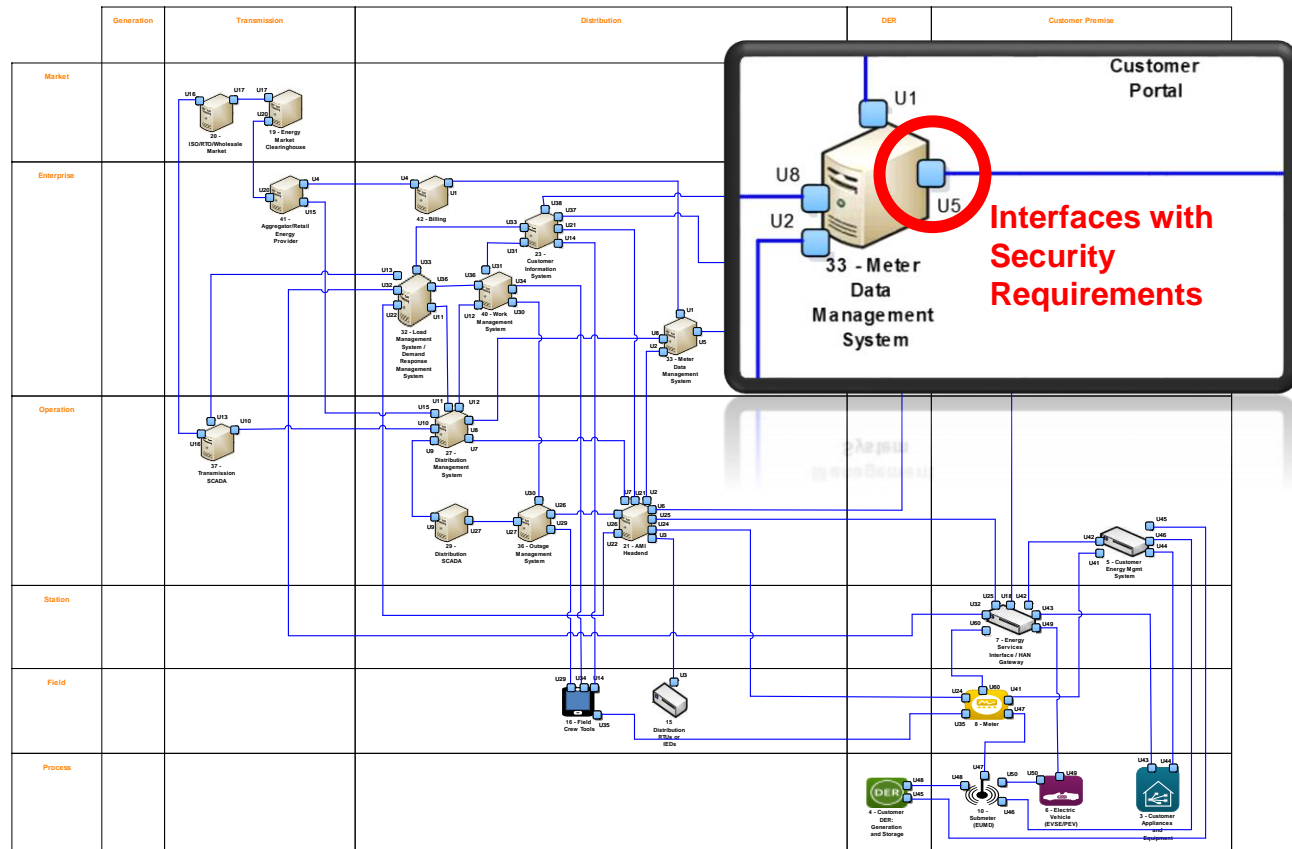


Reference Architecture



▶ Example Model: NIST LRM Scenario „Smart Metering“

▶ Click-through model: www.en-trust.at/NISTIR

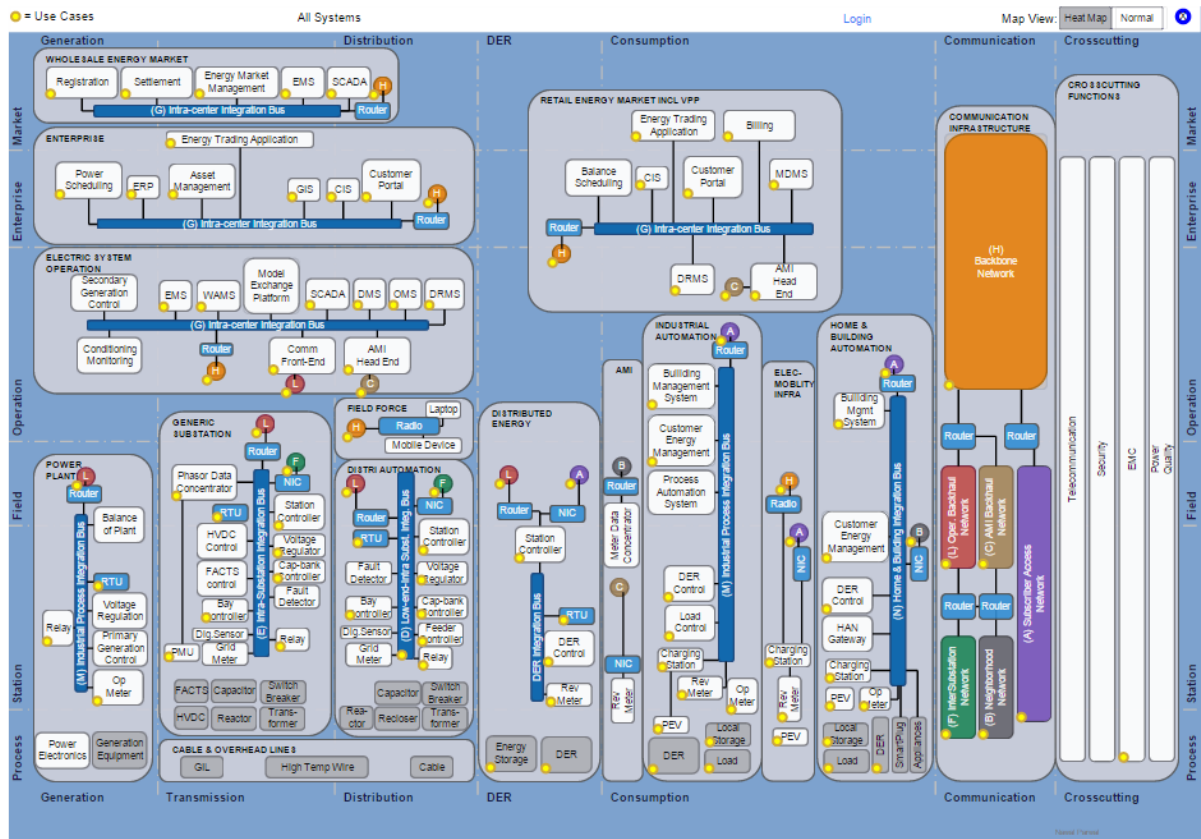


Reference Architecture



Utilization of standards for communication

- Interactive IEC standards map: <http://smartgridstandardsmap.com/>



How to build a house?



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Architecture Development

Basic Views

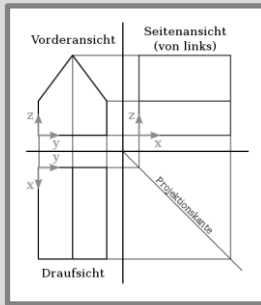
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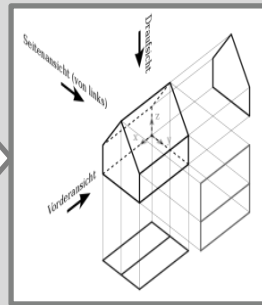
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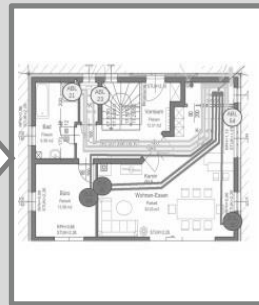
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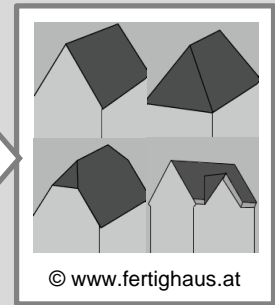
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Plumber, Electrician, Owner,...

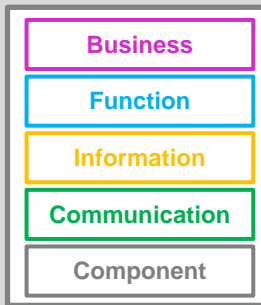


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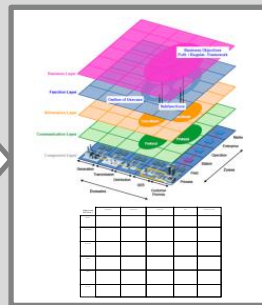


My individual house

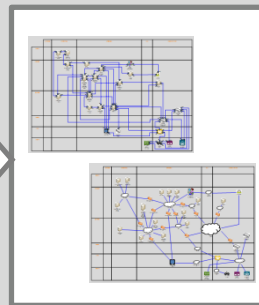
Smart Grid



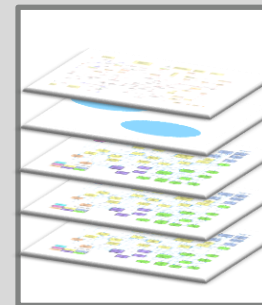
Functional and architectural aspects



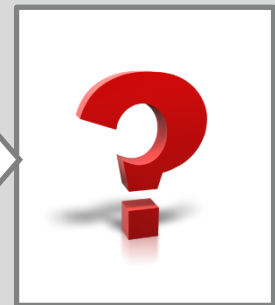
SGAM-Toolbox



Concerns & Views



ENTSO-E Role Model, NIST LRM,...



Solutions ???

Applications and Experiences

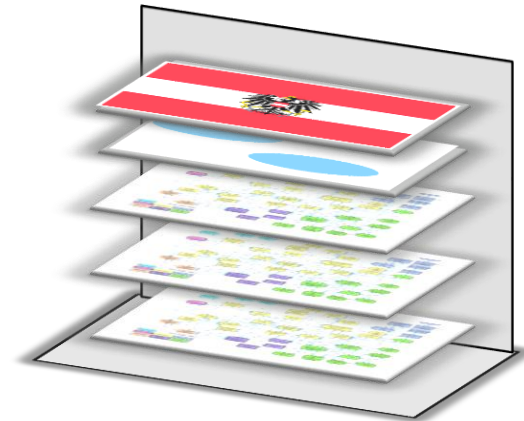


▸ **Project „RASSA“**

- „Reference Architecture for a Secure Smart Grid in Austria“

▸ **Elements of the project**

- Alignment of LRM with Austrian aspects
 - e.g. regulatory aspects)
- Integration of Austrian „Smart Metering Use Cases“
- Expansion of NIST LRM:
 - „Flat“ structure → Business Actors, Logical Actors, Physical Components
- Update of SGAM Toolbox
 - Implementation of (free) Add-In



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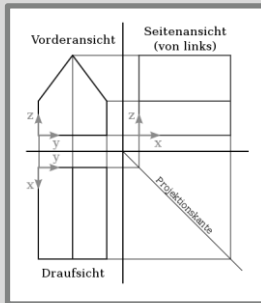
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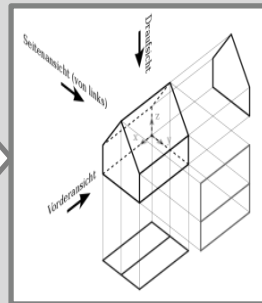
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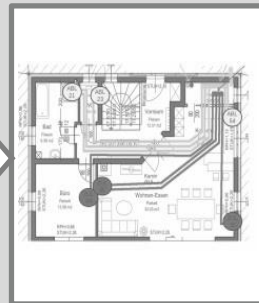
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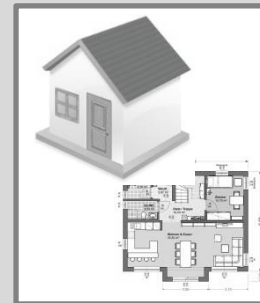
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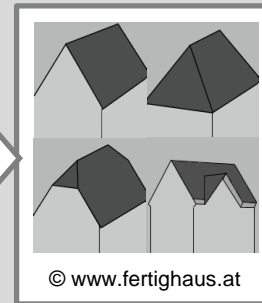
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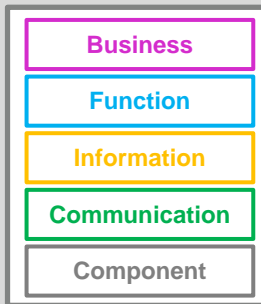
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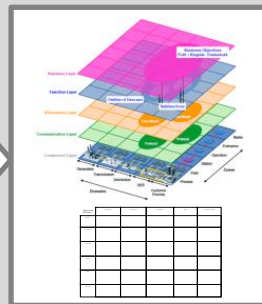
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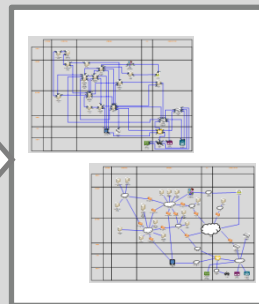
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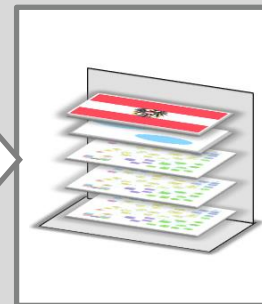
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Concerns & Views



ENTSO-E Role Model, NIST LRM,...



Solutions



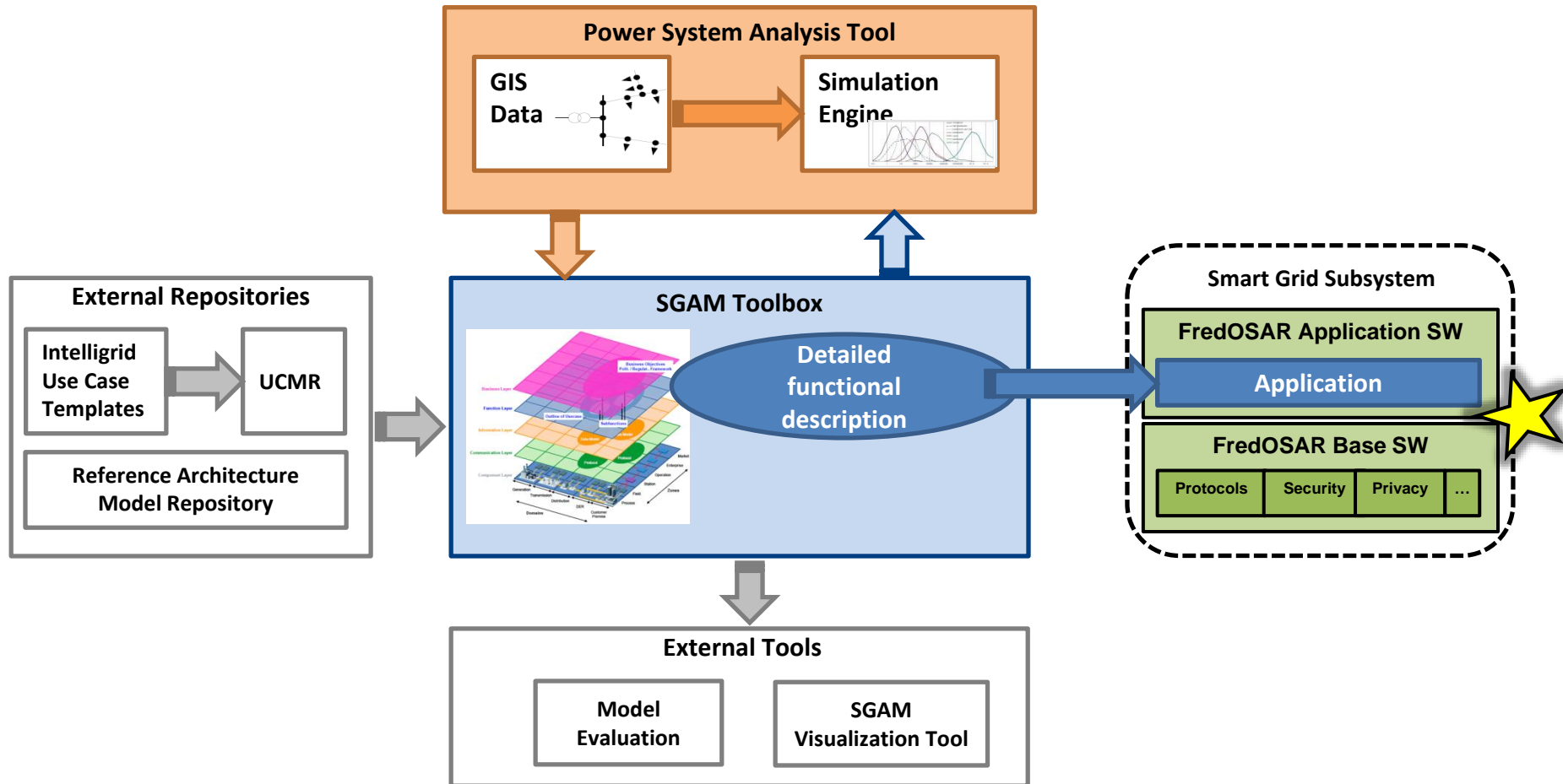
▸ Technical Aspects

- *Appear sound so far*
- *Interoperability under investigation*
- *Flat structure of NIST LRM vs. 3D structure of SGAM*
- *Extendability*
 - *New Interfaces*
 - *New Actors*
- *Dependability*
 - *Security concept valuable*
 - *Taxonomy for dependability missing*

▸ Applicability & Acceptance

- Used in different projects
 - Not limited to Europe
- Indication: Youtube Tutorials
 - 116 nations
 - 42k minutes watched so far
- Easy for engineers with general modeling experience
- Difficult for DSOs
 - → „Organizational Development“
- → Trainings supportive

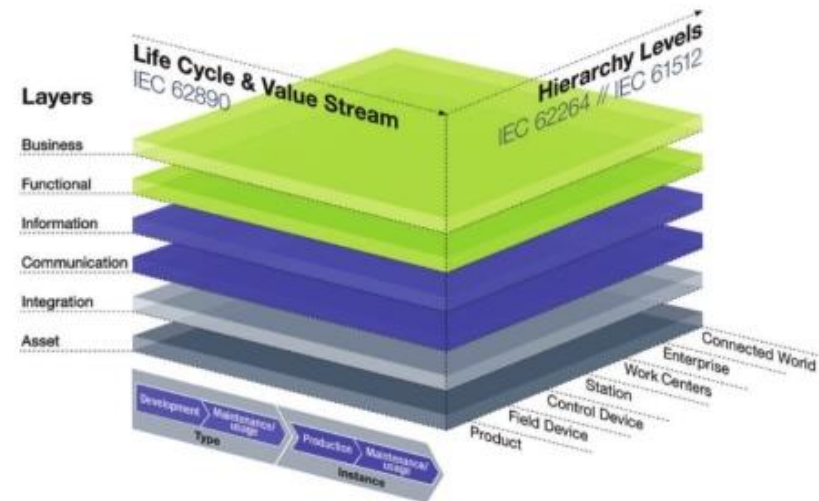
Present Work: Toolchain Integration



Present Work: Portability



- ▶ **Industry 4.0**
 - ▶ „Reference Architecture Model for Industry 4.0 (RAMI 4.)“
 - ▶ RAMI 4.0 Toolbox
- ▶ **Automotive**
 - ▶ Project started
 - ▶ Interoperability „Vehicle 2 Smart City“
- ▶ **Smart City**
 - ▶ Contribution to IEC SC Smart Cities, WG 3 Reference Architecture



Further Reading



- ▶ **Downloads & Publications available at www.en-trust.at**
 - ▶ C. Neureiter, D. Engel, and M. Uslar, “Domain Specific and Model Based Systems Engineering in the Smart Grid as Prerequisite for Security by Design,” *Electronics*, vol. 5, iss. 2, p. 24, 2016
 - ▶ C. Neureiter, M. Uslar, D. Engel, and G. Lastro, “A Standards-based Approach for Domain Specific Modelling of Smart Grid System Architectures,” in *Proceedings of International Conference on System of Systems Engineering (SoSE) 2016*, Kongsberg, Norway, 2016, pp. 1-6. Best Paper Award.
 - ▶ C. Neureiter, S. Rohjans, D. Engel, C. Dänekas, and M. Uslar, “Addressing the Complexity of Distributed Smart City Systems by Utilization of Model Driven Engineering Concepts,” in *Proceedings VDE Kongress 2014*, 2014, pp. 1-6.
- ▶ *And many others... ;-)*

...do you want to learn more?



Christian Neureiter
neureiter@successfactory.cc