Curriculum for

Certified Professional for Software Architecture (CPSA)®
Advanced Level

Module GREEN

Green Software - Development of resource-efficient applications

LocalBuild-EN-20260205

International Software Architecture
Qualification Board

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The abbreviation "e. V." is part of the iSAQB's official name and stands for "eingetragener Verein" (registered association), which describes its status as a legal entity according to German law. For the purpose of simplicity, iSAQB e. V. shall hereafter be referred to as iSAQB without the use of said abbreviation.

Learning Goals Overview

Introduction: General information about the iSAQB Advanced Level

What is taught in an Advanced Level module?

- The iSAQB Advanced Level offers modular training in three areas of competence with flexibly designable training paths. It takes individual inclinations and priorities into account.
- The certification is done as an assignment. The assessment and oral exam is conducted by experts appointed by the iSAQB.

What can Advanced Level (CPSA-A) graduates do?

CPSA-A graduates can:

- Independently and methodically design medium to large IT systems
- In IT systems of medium to high criticality, assume technical and content-related responsibility
- Conceptualize, design, and document actions to achieve quality requirements and support development teams in the implementation of these actions
- Control and execute architecture-relevant communication in medium to large development teams

Requirements for CPSA-A certification

- Successful training and certification as a Certified Professional for Software Architecture, Foundation Level® (CPSA-F)
- At least three years of full-time professional experience in the IT sector; collaboration on the design and development of at least two different IT systems
  - Exceptions are allowed on application (e.g., collaboration on open source projects)
- Training and further education within the scope of iSAQB Advanced Level training courses with a minimum of 70 credit points from at least three different areas of competence
- Successful completion of the CPSA-A certification exam

CPSA-A®
Certified Professional for Software Architecture
Advanced Level

Essentials

What does the module “GREEN” convey?

While IT was long seen as the solution to many problems associated with climate change, it has now itself become the subject of optimisation considerations. Inefficient programming, often caused by the need for a fast time-to-market, has often been compensated for by ever faster hardware or more resources in the cloud. This path must be abandoned. The CO_2 emissions caused by software must be consistently reduced. The increasing use of AI-based systems further exacerbates this problem, as the training and operation of large models in particular consume considerable amounts of energy and resources.

In the GREEN module, participants learn to take a holistic view of the topic of green software. This begins with the role of IT in halting climate change, an introduction to current regulations, the requirements of various stakeholders, and the identification of areas for action in companies. From there, it moves on to measuring and monitoring CO_2 emissions and energy consumption, before arriving at the core topic of software development. This central area covers the energy efficiency of various software architectures, energy-efficient data handling, and optimised algorithms. Another focus is on the influence of AI systems – from the development of resource-efficient models to the evaluation of the energy requirements of training and inference processes. In addition, the relationship between quality requirements and energy efficiency is analysed, for example, how performance, scalability and sustainability can be reconciled. Another important component is cloud computing, both in terms of selecting sustainable providers and the possibilities for low-carbon operation. Finally, options for improving energy efficiency in the development process are considered.

By the end of the module, participants will be familiar with the key levers for reducing CO_2 in IT. They will be able to assess the impact of software architectures and AI solutions on the energy balance, identify pitfalls in data handling and evaluate the consequences of selecting technical components. With regard to the cloud, they will know how to use the services and tools offered in a targeted manner for energy-efficient AI and software development.

Curriculum Structure and Recommended Durations

Content	Recommended minimum duration (minutes)
1. Climate change, opportunities of digitalisation, role of IT, basic concepts	45
2. Principles, regulation and effects on companies	60
3. Quality	45
4. Measurement and monitoring	135
5. Software development	75
6. Software architecture	150
7. Operation	105
8. Artificial intelligence and sustainability	60
9. Energy-efficient development process	45
Total	720 (12h)

Duration, Teaching Method and Further Details

The times stated below are recommendations. The duration of a training course on the GREEN module should be at least 2 days, but may be longer. Providers may differ in terms of duration, teaching method, type and structure of the exercises, and the detailed course structure. In particular, the curriculum provides no specifications on the nature of the examples and exercises.

Licensed training courses for the GREEN module contribute the following credit points towards admission to the final Advanced Level certification exam:

Methodical Competence:	10 Points
Technical Competence:	10 Points
Communicative Competence:	0 Points

Prerequisites

Participants **should** have the following prerequisite knowledge:

- Practical experience in the design and development of small to medium-sized software systems
- Knowledge of the life cycle of software systems
- Dealing with quality requirements
- Practical experience in monitoring software systems
- Practical programming experience

Knowledge in the following areas may be **helpful** for understanding some concepts:

- First practical experience with performance engineering
- First practical experience with common cloud providers
- First practical experience with CI/CD pipelines

Structure of the Curriculum

The individual sections of the curriculum are described according to the following structure:

- **Terms/principles**: Essential core terms of this topic.
- **Teaching/practice time**: Defines the minimum amount of teaching and practice time that must be spent on this topic or its practice in an accredited training course.
- **Learning goals**: Describes the content to be conveyed including its core terms and principles.

This section therefore also outlines the skills to be acquired in corresponding training courses.

Supplementary Information, Terms, Translations

To the extent necessary for understanding the curriculum, we have added definitions of technical terms to the iSAQB glossary and complemented them by references to (translated) literature.

1. Climate change, opportunities of digitalisation, role of IT, basic concepts

Duration: 45 min	Practice time: none

1.1. Terms and Principles

Climate change, consumption of IT, savings through IT, savings in IT, sustainability, CO_2, CO_2 equivalents, CO_2 intensity, CO_2 footprint, CO_2 handprint, negative external effects, watts, joules, efficiency, effectiveness

1.2. Learning Goals

LG 1-1: Recognising and addressing the global challenges of climate change

Participants are familiar with the global challenges of climate change. They know the increasing energy and resource requirements of IT and their main drivers. They can explain why IT must also address the issue of resource and energy efficiency.

LG 1-2: Knowing ways to save energy through digitalisation

Participants know the possibilities for saving energy and CO_2 through digitalisation. They know the sectors that particularly benefit from digitalisation. The difference between savings in IT and through IT is known.

LG 1-3: Categorising and quantifying IT energy consumption and know its drivers

Participants can quantify the energy consumption of information technology, categorise it in relation to other sectors and name the main drivers. They are familiar with trends and developments in IT and key levers for greater sustainability.

LG 1-4: Knowing the fields of action for saving CO_2

The participants know the fields of action for saving CO_2:

- Energy efficiency - Consume as little energy as possible.
- Hardware efficiency - Use as little hardware as possible.
- CO_2 emission efficiency - Consume energy when and where it is generated in the "greenest" way.

1.3. References

[bitkom 2021], [Brundtland 1987]

2. Principles, regulation and effects on companies

Duration: 60 min	Practice time: none

2.1. Terms and Principles

Energy efficiency, certifications (e.g. Blue Angel, TCO), regulatory requirements (e.g. CSRD, ESD), Greenhouse Gas Protocol (GHG Protocol)

2.2. Learning Goals

LG 2-1: Knowing the regulations and their requirements

Participants know the regulatory framework and the requirements it contains for saving CO_2. They know the existing certifications, such as the Blue Angel, and can use them appropriately in their work. Participants are familiar with standards such as ESG (Environmental Social Governance) and CSRD (Corporate Sustainability Reporting Directive) and their effects and consequences for companies.

LG 2-2: Knowing and applying the Greenhouse Gas Protocol

Participants are familiar with the Greenhouse Gas Protocol (GHP). They are able to explain the scopes and assign emissions to the scopes. They can explain which scopes are affected when operating software in the cloud or on premise. Participants are familiar with ISO 14064-1 as a derivation of the Greenhouse Gas Protocol.

LG 2-3: Positioning energy efficiency as a field of action in the company

The participants know the motivation for placing green software in the company and the arguments and addressees for successfully anchoring it in the company. They can set sensible targets for the reduction of greenhouse gases for companies. Participants can explain what requirements third parties have along the value chain and how these affect their own company.

LG 2-4: Knowing the stakeholders in the context of green IT and their prioritisation

Participants know the requirements of the various stakeholders for energy-efficient software and the resulting fields of action. They know the areas with the greatest leverage for reducing greenhouse gases and can prioritize measures accordingly. Participants can classify different software systems and recognize the costs and benefits of optimization.

2.3. References

[Greenhouse Gas Protocol], [ISO 14064-1]

3. Quality

Duration: 30 min	Practice time: 15 min

3.1. Terms and Principles

Quality model, quality scenarios, quality objectives, ISO 25010, arc42

3.2. Learning Goals

LG 3-1: Knowing quality models and their relation to energy efficiency

Participants are familiar with different quality models and can describe quality attributes relating to energy efficiency and categorise them in the quality models. In addition, participants are able to formulate quality scenarios for quality attributes in the area of energy efficiency. Depending on the intended use and the quantity structure of the application, they can consciously decide whether the quality criteria are used for the application or for the optimisation of the development process.

LG 3-2: Dealing with the interactions between quality attributes and energy efficiency

Participants know the positive and negative interactions between quality attributes in the area of energy efficiency and other quality attributes. Based on this knowledge, they can recognise quality requirements that conflict with each other and develop alternative solutions to mitigate conflicts. In particular, the quality attributes of elasticity, scalability, modularity and resilience are discussed in more detail so that participants can assess their influence on energy efficiency.

3.3. References

[arc42], [ISO 25010]

4. Measuring and Monitoring

Duration: 75 min	Practice time: 60 min

4.1. Terms and Principles

Software Carbon Intensity (SCI), business metrics, proxy metrics, energy efficiency, categories of measurement methods, measurement tools

4.2. Learning Goals

LG 4-1: Bringing resources in relation to the service provided

Participants are able to relate resources to the service provided (business metric). They are familiar with the ISO standard Software Carbon Intensity (SCI) as a metric and understand how it can be used as a business metric.

LG 4-2: Knowing and applying measurement methods

The participants know the methodological procedure for measuring energy consumption and CO_2 intensity. They understand that it is generally not possible to evaluate/measure absolute consumption very precisely (especially in the cloud), but how to analyse trends instead. They know proxy metrics for CO_2 intensity.

Participants know how to set up meaningful scenarios for measuring energy efficiency.

- They know criteria for designing the scenarios (e.g. common processes, prioritisation according to frequency of use).
- They know which interfaces to use depending on the objective of the measurement (end-to-end scenarios, using APIs, etc.).
- They know tools for creating such scenarios.
- They can deal adequately with measurement inaccuracies (e.g. running scenarios multiple times, interpreting deviations).

Participants understand that the procedure for measuring energy efficiency is related to the procedure for measuring performance. Participants understand how to proceed systematically in order to narrow down consumption hotspots.

LG 4-3: Knowing and using measuring methods and tools

Participants know different categories of measurement methods and their areas of application. They understand how to combine tools from the different categories for an analysis. Categories include, for example:

- Hardware measurement tools. Measure consumption using external devices or on-chip sensors.
- Scenario-based measurement tools. Measurement of consumption in specific usage scenarios, usually in dedicated measurement environments and focused on specific software components.
- Server monitoring. Recording of consumption for the entire application in test and production systems.
- Programming language-specific measurement tools. Provide "whitebox" measurements within an

application.

- Measurement tools for web applications. Provide information about the network load generated by a page request, among other things.
- Carbon footprint tools from cloud providers. In cloud environments, energy consumption cannot be measured directly. Instead, you have to rely on tools provided by the provider or other estimation methods. Participants are familiar with the functionality and limitations of these tools (inaccuracy, relative data, necessary authorisations in the cloud console) as well as the challenges of comparing managed services with pure VMs.

4.3. References

[SCI], [Sustainable Web Design], [Tool Landscape], [Greenframe], [Green Metrics Tool], [Cloud Carbon Footprint]

5. Software development

Duration: 75 min	Practice time: none

5.1. Terms and Principles

Programming languages, ahead-of-time and just-in-time compilation, bytecode, machine code, garbage collection, data structures, algorithms, computational complexity, caching, data handling, data models

5.2. Learning Goals

LG 5-1: Know ways to increase energy efficiency in software development

Participants know the procedures and limits for optimising programs. They can distinguish sensible starting points from less worthwhile goals. Participants are familiar with the energy efficiency of various programming languages and can assess the areas of application for which they are suitable. They can evaluate the runtime behaviour and development speed of programming languages and make the right choice based on the requirements. They also understand the differences between ahead-of-time and just-in-time compilation, bytecode and machine code and the conflicting goals of garbage collectors.

LG 5-2: Know the effects and possibilities of optimisations

Participants are familiar with the principle of computational complexity and can evaluate and select algorithms in terms of their runtime and energy efficiency. They can use caches in connection with energy efficiency, know how they work (e.g. cache replacement) as well as the advantages and disadvantages. They know the possibilities and limitations of tools for detecting energy code smells.

LG 5-3: Know and apply procedures for energy-efficient data handling

Participants know methods for handling large amounts of data. They can assess data structures and operations on these data structures in terms of energy efficiency and make the right selection based on the given requirements.

Participants know the pitfalls of using database systems and can avoid them. They are able to evaluate and optimally select different approaches for mapping relationships between entities on the basis of business requirements and quality requirements.

5.3. References

[Pereira et al. 2021]

6. Software architecture

Duration: 90 min	Practice time: 60 min

6.1. Terms and Principles

Architecture styles, monolith, microservices, modulith, Event-driven architecture, serverless, inter-process communication, databases, green IT patterns

6.2. Learning Goals

LG 6-1: Knowing and understanding architectural styles and their relation to energy efficiency

Participants can assess different architectural styles such as distributed systems, structured monoliths or serverless and their impact on energy efficiency. In addition, they are able to assess the difference between stateless and stateful components in terms of energy requirements. Participants are familiar with the principles of cloud-native architectures and their impact on energy efficiency.

LG 6-2: Knowing communication and its impact on energy efficiency

Participants are familiar with different types of communication (synchronous versus asynchronous) between building blocks in relation to the provision of data and the formats and protocols used (text-based versus binary protocols) with regard to energy efficiency. They are able to evaluate the influence of data compression on the transferred data volume and know that energy efficiency is positively influenced by a reduction in call frequency and data volume.

LG 6-3: Knowing database models and their characteristics in relation to energy efficiency

Participants are familiar with different types of database models (relational, NoSQL, etc.) and different database systems (Postgres, DB2, Oracle, etc.) and can make the right choice in terms of energy efficiency. They are able to select a suitable service model (self-hosting versus cloud-based managed service) for their data storage.

LG 6-4: Knowing and applying specific Green IT patterns

Participants are generally familiar with patterns such as those of the Green Software Foundation to improve the energy efficiency of an architecture. They are knowledgeable with the W3C’s Web Sustainability Guidelines on energy efficiency, which must be taken into account in web design. They are familiar with strategies such as browser caching, the use of a CDN and edge caching, and are able to implement these in their applications. They are familiar with different file formats and types of graphic elements (e.g. animations) and are able to assess their energy efficiency.

6.3. References

[GSF Patterns], [W3C]

7. Operations

Duration: 75 min	Practice time: 30 min

7.1. Terms and Principles

Power Usage Effectiveness (PUE), Server Idle Energy Coefficient (SIEC), Renewable Energy Factor (REF), Carbon Usage Effectiveness (CUE), Water Usage Effectiveness (WUE), service models, deployment models, cloud provider, GreenOps

7.2. Learning Goals

LG 7-1: Quantifying the energy efficiency of data centres and hardware

Participants can assess the energy efficiency of a data centre. They know the Power Usage Effectiveness (PUE) and its advantages and disadvantages.

Participants know the power-load relationship of hardware. They can calculate and estimate the Server Idle Energy Coefficient (SIEC).

Participants are also familiar with other key figures, including the Renewable Energy Factor (REF), Carbon Usage Effectiveness (CUE) and Water Usage Effectiveness (WUE). They can calculate and evaluate these key figures and know how to improve them.

LG 7-2: Knowing cloud service & deployment models and assessing them in terms of energy efficiency

Participants know the main categories of cloud computing services (cloud service models), in particular "Infrastructure as a Service", "Platform as a Service", "Software as a Service" and "Serverless". They can name the main characteristics of these models and weigh up where and how they differ in terms of energy efficiency and CO_2 emission efficiency and where they are similar.

Participants know the different deployment models for cloud environments, in particular "public cloud", "private cloud", "hybrid cloud" and classic on-premise operation. They can demonstrate the opportunities and risks of these variants in terms of energy efficiency and CO_2 emission efficiency. In particular, the energy efficiency of data centres, flexibility in the selection of hardware, overprovisioning and data traffic must be taken into account.

LG 7-3: Evaluating and selecting cloud providers according to ecologically sustainable aspects

Participants are able to assess ecologically sustainable aspects of the various providers in order to be able to take these into account when making a selection. To this end, they know how to obtain the following information, among others

- Information on the current status of a provider’s emissions (e.g. sustainability reports, environmental reports).
- Measures that providers are currently implementing to reduce or offset emissions.
- Roadmap and climate targets of providers for the future.
- Assess the greenwashing risks of providers.

In addition, participants know the possibilities and limitations of providers when monitoring emissions from their own resource use, as provided by the providers' carbon/environmental dashboards.

LG 7-4: Knowing operational antipatterns

Participants are familiar with the challenges of energy-efficient operation and typical anti-patterns such as overprovisioning due to a lack of monitoring, a lack of automation in provisioning or unfavourable geographical distribution.

LG 7-5: Carrying out CO_2 optimisation in the cloud

Participants are familiar with the terms "FinOps" and "GreenOps" and understand how they are related. They know how and to what extent they can influence CO_2 emissions at individual cloud providers by, among other things,

- Selecting zones with low-emission energy supply.
- Dimensioning resources sparingly and only scaling them when required.
- Optimising demand in terms of time and location with regard to emissions and resource availability ("time shifting", "location shifting")
- Autoscaling.
- Utilise efficient data storage (according to access path and frequency).
- Reduction or shortening of network traffic.
- Serverless computing.
- Use of managed services.

7.3. References

[Avelar et al. 2012], [Energy Efficiency Report], [Ackermann et al. 2022], [ISO/IEC 30134-9:2022], [ISO/IEC 30134-3:2016], [ISO/IEC 30134-8:2022]

8. Artificial intelligence and sustainability

Duration: 60 min	Practice time: none

8.1. Terms and Principles

Green AI, sustainable AI, model training, inference, foundation models, transfer learning, fine-tuning, model compression, quantization, pruning, knowledge distillation, edge AI

8.2. Learning Goals

LG 8-1: Understanding the environmental impact of AI systems

Participants understand the environmental impact of AI systems throughout their entire life cycle. They can distinguish between the phases of data collection, training, deployment, inference and maintenance, and explain their respective energy and resource requirements. They can apply the terms operational carbon and embodied carbon to AI systems.

LG 8-2: Evaluating energy-efficient AI architectures

Participants are familiar with basic architectural approaches for energy-efficient AI systems, e.g.:

- Edge vs. cloud inference
- Centralised vs. distributed model architectures
- Batch vs. real-time processing
- Reuse vs. retraining

They can compare these approaches in terms of energy efficiency, cost, latency and accuracy.

LG 8-3: Knowing and classifying optimisation techniques for AI models

Participants are familiar with common techniques for reducing the resource requirements of AI models, in particular:

- Transfer learning and fine-tuning
- Quantisation
- Pruning
- Knowledge distillation
- Use of small, specialised models instead of large foundation models

They can evaluate these techniques in terms of training effort, inference costs, model quality and energy consumption.

LG 8-4: Recognising trade-offs between quality and energy efficiency in AI systems

Participants understand the trade-offs between classic quality attributes (e.g. accuracy, robustness, latency, scalability) and energy efficiency in AI systems. They can make these trade-offs explicit and take them into account in architectural decisions. Participants are familiar with the concepts of green AI and sustainable AI. They understand that efficiency gains can lead to a rebound effect and can identify countermeasures.

8.3. References

[GSF Green AI], [Strubell et al. 2019], [Patterson et al. 2021]

9. Energy-efficient development process

Duration: 45 min	Practice time: none

9.1. Terms and Principles

Continuous deployment, continuous integration, deployment pipelines, test automation

9.2. Learning Goals

LG 9-1: Knowing CI/CD strategies and their resource requirements

Participants are familiar with various strategies of Infrastructure as Code, Continuous Integration and Continuous Deployments. This includes why and when these are usually used, what basic resource requirements they can have and how test execution and code analyses can affect these requirements.

LG 9-2: Optimising CI/CD processes

Participants are familiar with strategies for optimising resources and reducing CO_2 emissions from CI/CD processes. Examples of this include the use of peak shaving, time shifting and location shifting.

Participants know how to integrate energy efficiency measurements into the CI/CD pipeline. They understand how (negative) trends can be quickly identified and how data from different sources in the development process can be consolidated.

LG 9-3: Optimising the infrastructure

Participants are familiar with methods for optimising the development and deployment infrastructure. These include, for example:

- Consideration of the actual resilience required
- Efficiency advantages of containers over virtual machines
- Optimised layering in containers
- Reduction of container image size
- Use of caching for build and test artefacts

LG 9-4: Optimising the test strategy

Participants are familiar with ways to improve the resource efficiency of their test strategies and test environments. This includes, for example, the effect of different test types (load test, system test, integration test, unit test, …) on resource consumption and the reduction of this through test impact analyses and the demand-oriented, time-limited provision of appropriate test environments.

9.3. References

[Hammant 2017]

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