Übertragbarkeitskonzept zur Realisierung intelligenter Energieversorgungsnetze

Replicability Concept for Flexible Smart-Grids

Kurztitel: ReFlex

Schlussbericht

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Kurzfassung

Zentrales Ziel des Forschungsvorhaben Reflex (2016-2019) wardie Entwicklung eines Leitfadens zur Replizierbarkeit und Skalierbarkeit von Smart-Grid Lösungen, der ein Übertragbarkeitskonzept sowie Leitlinien beinhaltet. ReFlex basiert auf der Analyse von Pilotprojekten in vier großen Testregionen (Salzburg, Gotland, Hyllie und Rolle) sowie in vier kleineren Testregionen mit weniger als 15000 Einwohnern (Güssing, Hartberg, Biel-Benken, und Wüstenrot) in Österreich, der Schweiz, Deutschland und Schweden. Im Rahmen des ReFlex Projekts wurde eine Community of Practice (CoP) – eine Arbeitsgruppe bestehend aus Experten und Fachpersonen aus dem Smart-Grid und Energiebereich – eingerichtet. Diese sollte dazu dienen, den länderübergreifenden fachlichen Wissensaustausch zwischen Experten in den Testregionen zu fördern sowie komplexe Sachverhalte zum Thema Smart-Grid zu eruieren und diese in Workshops zu diskutieren und zu analysieren.

Im Laufe des Projektes wurde weiterhin ein Simulationstool entwickelt und am Beispiel der Demo-Site von Wüstenrot und Biel-Benken getestet. Das Tool nutzt die von EIFER entwickelten Modelle sowie die an Demo-Sites erhobenen Daten. Die ReFlex-Projektpartner ZSW und SUPSI stellten zusätzlich eigene Simulationsdaten zur Verfügung. Mit Hilfe dieses agentenbasierten Modells namens "ReflexBox", können Energiesysteme von Haushalten auf Basis des Referenzprojektes in Biel-Benken, Schweiz, an verschiedene Standorte repliziert und auf eine gewünschte Größe hoch- oder herunterskaliert werden. Darüber hinaus ermittelt das Simulationsmodell das Flexibilitätspotenzial des nachgebildeten Energiesystems. Dieses Modell kann Städte und Gemeinden sowie Verteilnetzbetreiber bei der Planung ihres lokalen Smart–Grid-Projektes unterstützen und kann Entscheidungsträger dabei helfen, zu verstehen was Flexibilität ist und welcher Nutzen damit verbunden ist.

Schließlich wurden basierend auf den Ergebnissen der Simulationsstudie, auf dem Feedback, das während der CoP Veranstaltungen gesammelt wurde, und der vom ReFlex-Forschungsteam durchgeführten Recherchen, Leitlinien ausgearbeitet, um die Demo-Regionen und die breitere Gruppe der europäischen Smart-Grid-Stakeholder bei der Umsetzung und Weiterentwicklung ihrer Smart-Grid-Initiativen und Replikationsprojekte zu unterstützen.

Der erste Teil des Leitfadens beschreibt vier sozioökonomisch relevante und technisch übertragbare Use-Cases (Anwendungsfälle), basierend auf Beispielen aus den acht Demo-Standorten des ReFlex-Projekts. Der zweite Teil enthält eine Checkliste und eine Toolbox, die Interessengruppen bei der Planung, Entwicklung und Implementierung von Use-Cases in Replikationsprojekten unterstützen. Darüber hinaus wurde eine Entscheidungshilfe zur Replizierbarkeit von Smart-Grid Projekten für politische Entscheidungsträger auf nationaler und europäischer Ebene erstellt.

Dieses Dokument ist in sechs Kapitel untergegliedert. Kapitel 1 bietet einen Überblick über das Vorhaben, die beteiligten Partner und die Projektziele, während Kapitel 2 die wichtigsten wissenschaftlichen Ergebnisse zusammenfasst. Kapitel 3 gibt Auskunft darüber, wie die Ergebnisse in den Folgeprojekten verwertet wurden. In Kapitel 4 sind die Forschungsergebnisse anderer Stellen auf dem Gebiet des Vorhabens dargestellt. Anschließend wird in Kapitel 5 der Aufbau und Funktionsweise des im Rahmen des Projekts entwickelten Simulationsmodells charakterisiert. Schließlich sind in Kapitel 6, die erfolgten und geplanten Veröffentlichungen der Ergebnisse vorgestellt. Der in Englisch verfasste ReFlex Leitfaden ist im Anhang beigefügt.

Inhalt

1 Projektübersicht

Ziel von ReFlex war die Entwicklung eines Übertragbarkeitskonzepts und eines Leitfadens zur Realisierung intelligenter Energieversorgungsnetze mit einem hohen Maß an individueller Anwendbarkeit. Dabei wurden technologisch machbare, marktbasierte und anwenderfreundliche Lösungen aufgezeigt.
Der Schwerpunkt lag auf Energieversorgungsstrukturen, bei denen ein großer Anteil der Energie aus erneuerbaren Energiequellen erzeugt wird. Diese sollten lokal und effizient durch die Kombination verschiedener Maßnahmen der Spannungsregulierung, Nachfragesteuerung und Speicherung genutzt werden.

ReFlex basierte auf der Analyse sowie der Weiterentwicklung von Pilotprojekten mit intelligenten Energieversorgungsstrukturen in vier großen Testregionen (Salzburg, Gotland, Hyllie und Rolle) sowie in vier kleineren Testregionen mit weniger als 15000 Einwohnern (Güssing, Hartberg, Biel-Benken, und Wüstenrot) in Österreich, der Schweiz, Deutschland und Schweden.
Aus dem aggregierten Wissen der ReFlex-Partner wurde ein Leitfaden zur Übertragbarkeit erarbeitet, welcher die Testregionen und darüber hinaus interessierte Kommunen, Gemeinden und Interessensgemeinschaften in Europa beim Einsatz und Ausbau intelligenter Netzte unterstützt.

Als Querschnittsaktivität innerhalb des ERA-Net fließen die gewonnenen Erkenntnisse in die zugehörige Wissensgemeinschaft ein.

Die Hauptziele von ReFlex waren:

- Die Einrichtung einer ReFlex ‚Community of Practice' (CoP), einer Wissensforums-Plattform, für den länderübergreifenden fachlichen Wissensaustausch zwischen den Testregionen; mit dazugehörigen Arbeitstreffen sowie Besuchen von Pilotprojekten vor Ort (Walkshops), organisiert für Fachleute, Interessensgruppenvertreter und Forscher.

- Das Erkennen von problematischen Sachverhalten von der CoP und die Untersuchung durch profunde Analyse oder anwendungsbezogene Forschung. Dies beinhaltete das Erheben von Daten für die empirische Beweisführung und Zukunftsszenarien für alle drei Forschungsebenen (gesellschaftliche Akzeptanz, Marktumfeld und Stand der Technik).

- Die Erarbeitung eines ReFlex-Leitfadens zur Übertragung von technologisch umsetzbaren, ökonomisch machbaren und anwenderfreundlichen Lösungen für intelligente Netze. Der Leitfaden umfasst ein Übertragbarkeitskonzept sowie Leitlinien, behandelt alle drei Forschungsebenen und führt gute Anwendungsbeispiele auf.

1.1 Stand der Wissenschaft zu Projektbeginn

Das Grid+ Projekt hat das Fehlen eines klaren und kohärenten Konzepts für die Übertragbarkeit eines Smart-Grid Pilotprojekts auf andere Standorte, angesichts der Unterschiede in den Bereichen Technologien, Marktbedingungen und gesellschaftliche Akzeptanz zwischen Länder und

Regionen, erkannt [Sigrist et al., 2016]. Die Agenda 2013-2022 für Forschung und Innovation des EEGI (European Electricity Grid Initiative) stellt die Notwendigkeit einer detaillierten Analyse der Übertragbarkeit von Smart-Grid Pilotprojekten fest [EEGI, 2013]. Insbesondere sollten die sozio-ökonomischen Aspekte sowie der Regulierungsrahmen in unterschiedlichen nationalen und regionalen Kontexten näher untersucht werden.

„Regarding regulatory and stakeholder-related factors there are two main barriers identified; stakeholder involvement and regulatory dependency. Stakeholder involvement, i.e. homonymous scalability and replicability factors acceptance, requires an increased attention in both convincing stakeholders to participate and in establishing rules to involve and make participating stakeholders. On the other hand the dependency on regulatory frameworks and the impact of market design require more attention. More uniformity in economic regulation, i.e. similar to the technical regulation might be envisaged." [May et al. 2015]

Bedeutende Wissenschaftler und politische Entscheidungsträger betonen, dass ein intensiver Wissensaustausch zu jedem Innovationsvorgang gehört. Im Rahmen des Projekts ReFlex wurde eine Wissensplattform aufgebaut, an der sich die Partner aus verschiedenen Pilotprojekten beteiligen konnten, um ihre Erfahrung auszutauschen. Die Wissensplattform ist ein etabliertes Instrument im Bereich des Wissensmanagements [Wenger et al., 2002]. Dieses Tool wurde schon mehrmals in Projekten erfolgreich angewandt und wurde dementsprechend im Rahmen des ReFlex Projekts eingesetzt.

Die Übertragbarkeit von Smart-Grid Technologien stellt eine bedeutende Rolle im Wandel zu einem nachhaltigen Energiesystem dar. Agentenbasierte Modellierung, eine etablierte Methode zur Simulation verteilter Netze und zur Dynamik sozialer Systeme, weist ein großes Potential auf. Damit können unterschiedliche Algorithmen und Modellierungen bzgl. ihrer Vor- und Nachteile in den verschiedenen Bereichen des Smart-Grids untersucht werden.

1.2 Wissenschaftliche und/oder technische Arbeitsziele

ReFlex folgte einem inter- und transdisziplinären Ansatz und erarbeitete einen Leitfaden, der auf empirischen Daten der Demonstrations- und Pilotprojekte sowie theoretischen Ansätzen beruht. Jedes derartige Konzept muss prinzipiell alle relevanten Aspekte des Wandels der Energiesysteme sowohl auf den drei Ebenen gesellschaftliche Akzeptanz (z.B. Nutzerakzeptanz, nachfrageseitig orientierte Innovationen), Marktumfeld (z.B. neue Geschäftsmodelle) und Stand der Technik (z.B. Standards, Skalierbarkeit von Soft- und Hardware) als auch die diese Ebenen verbindenden europäischen und nationalen Rahmenbedingungen (wie z.B. Sicherheitsbestimmungen und -aspekte, neue Leitlinien und Verordnungen) betrachten.

Um diese Vorgaben zu erreichen, verwendete ReFlex auf die folgenden methodischen Ansätze:

- Wissensgewinn von vorhandener Begleitforschung im Bereich von Smart-Grid-Anwendungen durch Datenauswertung und Nachforschung um den theoretischen Ansatz zu entwickeln und das Übertragbarkeitskonzept zu verfeinern: Da die Übertragbarkeit von Innovationen im

Bereich der Energiesysteme ein neues Forschungsfeld ist, wurde der Schwerpunkt auf fortlaufende Anwendungsbeispiele aus verschiedenen Ländern, international gewonnene Erfahrung mit der Anwendung in größerem Maßstab sowie den interregionalen und intersektoralen Wissensaustausch gesetzt.

- Simulation verschiedener Vorgehensweisen: Zur Verallgemeinerung und Validierung von Prozessen zur Übertragung und zur Unterstützung der Einführungsplanung bedient sich ReFlex agentenbasierter Simulationstechniken um die Annahme von Technologien innerhalb verschiedener Interessensgruppen und das diesbezügliche Verbraucherverhalten zu prognostizieren. Ein besonderer Schwerpunkt wurde hierbei auf die vorherige Folgenabschätzung öffentlicher und privater Vorgehensweisen bei maßstäblicher Vergrößerung gelegt. Durch die Nutzung simulierter Szenarien konnten verschiedene Vorgehensweisen in einer Vielzahl verschiedenartigster europäischer, nationaler und sozioökonomischer Zusammenhänge analysiert werden noch bevor die großmaßstäbliche Einführung begann.

- Bereitstellung eines Prozesses zur Beteiligung der verschiedenen Interessensgruppen durch die ‚Community of Practice' (CoP), einem allgemein anerkannten, wirksamen Werkzeug zum Erfahrungsmanagement: Dies wurde durch eine Reihe intensiver Arbeitstreffen erreicht, bei welchen aus laufenden oder abgeschlossenen Pilotprojekten aus Fehlschlägen gelernt wurde und erfolgreiche Smart-Grid-Lösungen übernommen und verbreitet wurden. Die ausgewogene Mischung aus größeren und kleineren Modellregionen, die geografische Verteilung der Modellregionen mit ähnlichen klimatischen Bedingungen und die Mischung zwischen stark und schwach regulierenden rechtlichen Rahmenbedingungen lieferte eine Vielfalt, die für den Erkenntnisgewinn in einer CoP optimal war.

- Feldforschung durch ein interdisziplinäres Team von Ingenieuren und Sozialwissenschaftlern als Handlungs- und Aktionsforschung: Fachleute der CoP lieferten forschungsrelevante Fragestellungen und waren ebenso die Hauptadressaten der Forschungsergebnisse, welche sowohl quantitative Analysen und Szenarien als auch die Analyse von sozioökonomischen und (über)staatlichen Aspekten der Übertragbarkeit mit einbezog. Dies umfasste die Datenerhebung von teilnehmenden Modellregionen, die statistische Analyse der Verteilung vorhandener Technologien, Prozesse sozialer Akzeptanz und schloss auch die statistische Analyse von empirischen Daten sowie Szenarienbildung anhand agentenbasierter Simulationstechniken ein.

Mit Hilfe dieses methodischen Ansatzes wurde die Übertragbarkeit innerhalb der CoP unterstützt, eine Validierung der Übertragbarkeitspläne in sämtlichen Ausprägungen ermöglicht, Überprüfungs- und Gestaltungsbedingungen geschaffen und schließlich der Leitfaden zur Übertragbarkeit entwickelt.

1.3 Planung und Ablauf des Forschungsvorhabens

Die Projektlaufzeit betrug drei Jahre und der Bearbeitungszeitraum reichte vom 01.04.2016 bis zum 31.03.2019. Die Meilensteine und Arbeitsschritte der jeweiligen Arbeitspakete sind in der folgenden Abbildung aufgeführt.

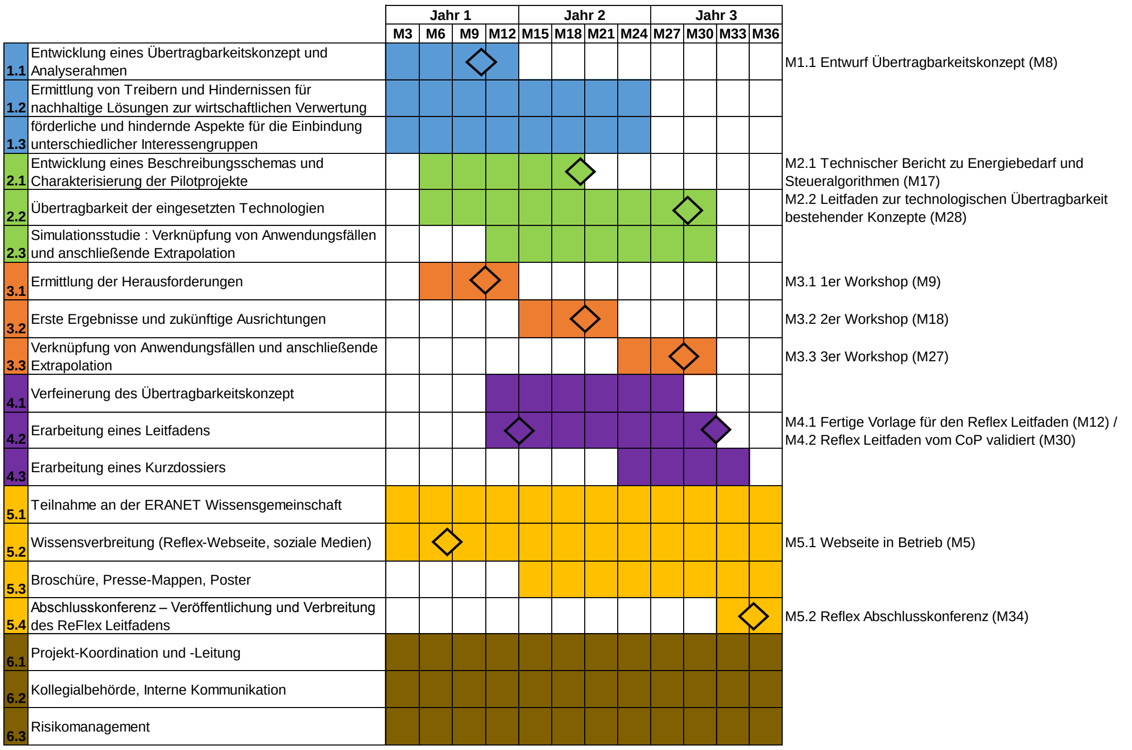


Abbildung 1: Projektplanung mit Meilensteinen (losgelöst von übergeordneten Projektzielen und AP-Struktur)

Die wissenschaftliche Fragestellung wurde in folgende sechs Arbeitspakete aufgeteilt:

- In AP1 *„Übertragbarkeitskonzepte und sozioökonomische Begleitforschung“* wurde ein Konzept erarbeitet, welches es ermöglicht, die Eigenschaften, Treiber und Barrieren von Smart-Grid-Demonstrationsprojekten hinsichtlich ihrer Übertragbarkeit zu analysieren, sowie das Verständnis für förderliche und hinderliche Aspekte am Markt und bei den beteiligten Akteuren zu vertiefen.

- In AP 2 *„Technologie-Bewertung und –Vergleich“* wurden die unterschiedlichen technologischen Lösungen hinsichtlich ihrer technischen Reifegrades, ihres Smart-Grid Reifegrades bewertet und ihre Skalierbarkeit mittels eines Simulationsmodels analysiert.

- Das Ziel des Arbeitspakets 3 *„Plattform zum Wissensaustausch“* ist der Aufbau einer Plattform zum Wissensaustausch, die die Entwicklung der Leitlinien zur Übertragbarkeit durch die Organisation von Workshops und Site-Visits aktiv unterstützt.

- AP4 *„Leitlinien zur Übertragbarkeit auf drei Forschungsebenen"* zielt auf die Entwicklung eines Leitfadens ab, welcher Leitlinien für die Übertragbarkeit von Lösungen für flexible intelligente Netze beinhaltet und als ‚ReFlex Leitfaden' veröffentlicht wurde. Zudem wurden die Schlüsselmerkmale für Entscheidungsträger zusammengefasst.

- AP5 *„Wissensgemeinschaft und Wissensverbreitung"* zielt auf Wissensaustausch mit der Wissensgemeinschaft und einer breiteren Öffentlichkeit ab.

- AP6 *„Projekt-Koordination und –Leitung"* zielt auf einen reibungslosen, effizienten und erfolgreichen Ablauf des Projekts ab.

1.4 Arbeitsteilung/Kooperationspartner

Das Konsortium bestand aus ReFlex-Partner aus den acht Testregionen sowie fünf wissenschaftlichen Partnern aus vier verschiedenen Ländern. Letztere waren für die Leitung der Arbeitspakete verantwortlich und trugen maßgeblich zum Erreichen der Arbeitsziele bei.

Das AIT war für die allgemeine Koordinierung des Projekts und den ReFlex Leitfaden (AP 4) verantwortlich und war an allen anderen Arbeitspaketen beteiligt. LiU war Leiter des AP1, das sich mit Übertragbarkeitskonzepte und sozioökonomische Begleitforschung befasste, und war an den Arbeitspaketen 3 und 4 beteiligt.

Der Schwerpunkt der Arbeiten von ZSW lag auf dem technologischen Vergleich im Arbeitspaket 2. Der Großteil der Arbeitsleistung von ZSW floss hier ein. ZSW war Leiter des AP2. Hierbei wurde das ZSW durch drei Unterauftragnehmer unterstützt. Dies sind die Gemeinde Wüstenrot, die Firma AVAT und die Hochschule für Technik, Stuttgart (HFT). Darüber hinaus war ZSW an AP1, 3, 4 und 5 beteiligt.

Die AVAT Automation GmbH realisiert Kraft/Wärme-Kopplungs-Lösungen, virtuelle Kraftwerke/ Smart-Grid-Verbundlösungen aus flexiblen Erzeugern, Lasten und Speichern kombiniert mit intelligenten Erzeugungs- und Lastmanagement. Sie unterstütze ZSW bei der technischen Beurteilung der verwendeten Technologien für die am Projekt beteiligten Smart-Grid Pilotprojekte (AP2) und war an der Formulierung von Strategien für die Replizierbarkeit von Smart-Grid Projekten, insbesondere bei den technologischen Aspekten (AP4) sowie an AP3 beteiligt.

HFT stellte Informationen und Erfahrungen, Kenngrößen, und Details der technischen Umsetzung aus dem Projekt „EnVisaGe" bereit und hat Wärmebedarfsdaten der in ReFlex untersuchten Smart-Grid Projekte (AP2) verarbeitet. Darüber hinaus war HFT an AP1, 3 und 5 beteiligt.

Die Gemeinde Wüstenrot brachte die im Forschungsprojekt *EnVisaGe Kommunale netzgebundene Energieversorgung – Vision 2020 am Beispiel der Gemeinde Wüstenrot* gemachten Erfahrungen, Kenngrößen und Details der technischen Umsetzung ins Projekt ein und war Veranstaltungsort eines zweitägigen Workshops.

Tabelle 1: Überblick Projektstruktur, Arbeitspakete, AP-Leitung und Teilnahme

	AIT - Austrian Institute of Technology GmbH	**EIFER** – Europäisches Institut für Energieforschung EDF-KIT EWIV	**LiU** – Linköping University	**SUPSI** - University of Applied Sciences and Arts of Southern Switzerland	**ZSW** - Zentrum für Sonnenenergie und Wasserstoffforschung Baden-Württemberg
AP1 – Übertragbarkeitskonzepte und sozioökonomische Begleitforschung	Beteiligung		AP-Leitung	Beteiligung	Beteiligung
AP2 – Technologie-Bewertung und -Vergleich	Beteiligung	Beteiligung		Beteiligung	AP-Leitung
AP3 – Plattform zum Wissensaustausch	Beteiligung	AP-Leitung	Beteiligung	Beteiligung	Beteiligung
AP4 – Leitlinien zur Übertragbarkeit auf 3 Forschungsebenen	AP-Leitung	Beteiligung	Beteiligung	Beteiligung	Beteiligung
AP5 –Wissensgemeinschaft und Wissensverbreitung	Beteiligung	Beteiligung		AP-Leitung	Beteiligung
AP6 – Projekt-Koordination und -Leitung	AP-Leitung				

Die Projektpartner AIT, LiU und SUPSI stellten die Daten der Pilotregionen aus Österreich, Schweden und der Schweiz bereit und haben sich zusammen mit EIFER und ZSW an der Erarbeitung des Leitfadens beteiligt.

EIFER hat mit der Unterstützung vom AIT eine Plattform zum Wissensaustausch aufgebaut (AP3) und war für die Simulationsstudien im Rahmen des APs 2 verantwortlich. SUPSI war Leiter des AP 5 (Wissensgemeinschaft und Wissensverbreitung) und hat sich an den Arbeitspaketen 2,3 und 4 beteiligt. Die Partner der Demoregionen haben an der Plattform zum Wissensaustausch teilgenommen, und Daten für die APs 1 & 2 aufbereitet und bereitgestellt.

Das Projektmanagement erfolgte durch die Projektleitungsgruppe, bestehend aus dem Projektkoordinator, den AP-Leitern sowie den nationalen Projektträgern, welche die administrativen, rechtlichen und finanziellen Fragen behandelt haben. Diesem Gremium wurde in regelmäßigen Abständen der aktuelle Projektverlauf dargelegt, sodass gegebenenfalls Korrekturen vorgenommen werden könnten.

2 Wissenschaftliche Ergebnisse

Im Folgenden werden die wissenschaftlichen Ergebnisse mit Zuordnung zu den jeweiligen Arbeitspaketen näher beschrieben.

2.1 AP1 - ReFlex Replizierbarkeitskonzept

Als konzeptioneller Rahmen wurde das ReFlex-Replizierbarkeitskonzept unter der Leitung der Linköping University entwickelt, welches neben den rein technischen Aspekten eines Smart-Grid-Pilotprojekts die sozioökonomischen Faktoren zum Skalieren und Replizieren eines solchen mit einbezieht. Das Replizierbarkeitskonzept wurde mit allen Projektpartnern und Interessengruppen erarbeitet und diskutiert. Es bietet theoretische Grundlagen und bildet die strukturelle Basis des ReFlex-Leitfadens.

2.2 AP2 - Charakterisierung der Pilotprojekte

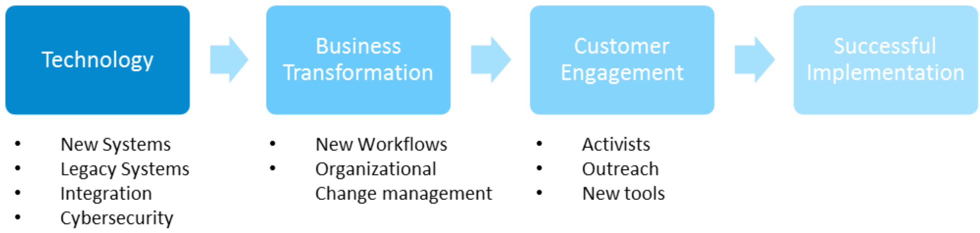


Abbildung 2: Erfolgreiche Implementierung neuer Smart-Grid-Technologien [Ketchledge, 2015]

Wie in Abbildung 2 gezeigt, sind neue Technologien die Grundlage für ein erfolgreiches Smart-Grid-Projekt. Allen ReFlex-Pilotprojekten gemeinsam, war die Idee, ein nachhaltiges, dekarbonisiertes und intelligentes Energiesystem umzusetzen. Die Umstellung von einer alten Top-Down-Infrastruktur mit großen zentralen Kraftwerken auf eine dezentrale Infrastruktur mit erneuerbaren Energiequellen erfordert die Einbettung von Geräten mit neuen technologischen Eigenschaften in eine bestehende aber in neuer Art genutzte Infrastruktur oder in eine neue Infrastruktur. Es benötigt weiterhin Akteure, die ein neues Geschäftsfeld entwickeln („Business Transformation") und die Ansprache von Kunden, um deren Engagement bzw. Ihre Akzeptanz zu gewinnen, um Smart-Grid Technologien für ein dekarbonisiertes Energiesystems erfolgreich implementieren zu können (Abbildung 2).

Im Rahmen des Projekts wurden unter der Leitung des ZSW alle ReFlex-Pilotprojekte in Bezug auf die eingesetzten Technologien analysiert und bewertet mit den Zielen,

- einen Überblick über die bei den Pilotprojekten verwendeten Technologien und deren Reifegrad zu geben (siehe Abschnitt 2.2.1),
- Erfahrungen hinsichtlich Sektorkopplung, also funktionale Interaktion verschiedener Energiesektoren (Elektrizität, Wärme, Mobilität) und hinsichtlich technologischer Synergien aufzuzeigen (siehe Abschnitt 2.2.2),

- die zur Verfügung stehende Flexibilität der Technologien einzuordnen (siehe Abschnitt 2.2.3) und
- Best-Practice-Technologien für bestimmte Anwendungsfälle (siehe Abschnitt 2.2.4) hervorzuheben.

Zur Entwicklung des technologischen Teils des Leitfadens im Rahmen von Arbeitspaket 2 (Leitung ZSW), wurden auf Grundlage der von den Demo-Sites erstellten Poster, Interviews und Berichten (anlässlich der CoPs in Wüstenrot im März 2017 und Malmö im Okober 2017, sowie Site-Visits in Biel Benken im Januar 2017 und Salzburg im Juni 2017 die verschiedenen Sektoren, Technologien und Randbedingungen recherchiert und analysiert.

2.2.1 Eingesetzte Technologien und deren Reifegrad

Tabelle 2: Übersicht über die eingesetzten Technologien bei den ReFlex Pilotprojekten

	Technology	Biel-Benken CH	Gotland SE	Güssing AT	Köstendorf AT	Hartberg AT	Malmö SE	Wüstenrot DE	TRL	SGRL
Electricity	Biomass			✓	✓	✓	✓	✓	9	9
	Photovoltaic Plants	✓	✓	✓	✓	✓	✓	✓	9	8
	Wind Power		✓			✓	o	o	9	8
	Hydro								-	-
Heat	Geo- / Agrothermal							✓	8	8
	Heat Pumps	✓	✓	✓	✓	✓	✓	✓	9	7
	District Heating Network			✓	✓	✓	✓	✓	9	8
	Solar Thermal			✓		✓	✓	✓	9	8
	Biomass Block-Type Thermal Power			✓	✓	✓	✓	✓	9	8
	Biogas / Biofuel			✓			o	o	8	8
Mobility	Electric Cars	✓		✓	✓	✓	✓	✓	9	7
	Car Charger	✓		✓	✓	✓	✓	✓	9	7
Storage	Electric Battery Storage	✓	o		✓	✓	✓	✓	9	8
	Thermal Buffer Storage	✓			✓	✓		✓	9	8
Data Communication	Smart Grid With Data Communication	✓	✓	✓	✓	✓	✓		7	7
Buildings	Building Energy Manager (DSM)	✓	✓	✓	✓	✓	✓	✓	7	7
	High Efficiency Buildings				✓		✓	✓	9	-
Clients	Residential Consumers	✓	✓	✓	✓	✓	✓	✓	-	-
	Industrial Consumers		✓	✓		✓		✓	-	-

In Tabelle 2 ist die Zusammenstellung der in den untersuchten Pilotprojekten eingesetzten Technologien dargestellt. Hervorzuheben ist die Photovoltaik, welche bei allen Pilotprojekten für die Stromerzeugung eingesetzt ist. Ebenfalls weit verbreitet ist Biomasse. Die Windenergie wurde nur in zwei der sieben untersuchten Pilotprojekte umgesetzt (das Pilotprojekt Rolle-Lausanne war noch nicht gestartet als die Analyse durchgeführt wurde). Grund hierfür sind gesetzliche Rahmenbedingungen, höhere Investitionskosten, wenige Standortmöglichkeiten und geringere öffentliche Akzeptanz im Vergleich zur Solarenergie.

Wärmepumpen sind die einzige Technologie zur Wärmeerzeugung, die in allen Pilotprojekten eingesetzt werden. Grund hierfür ist die einfache und effiziente Kopplung von Strom- zu Wärmesystemen durch die Wärmepumpe. Solarthermie, (oberflächennahe) Geothermie oder Biomasse-BHKWs in Verbindung mit Wärmenetzen wurden ebenfalls häufig in der Praxis erprobt. Bei kommunalen Energieprojekten bilden Biomasse-Blockheizkraftwerke, die an ein (Fern-)Wärmenetz angeschlossen sind, die Schlüsseltechnologie für die Wärmeversorgung.

Basierend auf Standortbesuchen, Interviews und den Erfahrungen der Community of Practice (CoP), wurde verschiedenen Technologien ein Reifegrad (Technology Readiness Level - TRL) zugewiesen. Hierzu wurde zusätzlich die technologische Effizienz, Rentabilität und Akzeptanz in der Bevölkerung recherchiert, um einen gewichteten, technologischen Reifegrad zu ermitteln. Wie in der Tabelle 2 ersichtlich, haben alle Technologien einen sehr hohen TRL-Wert (8-9) und weisen somit einen erprobten Praxiseinsatz auf.

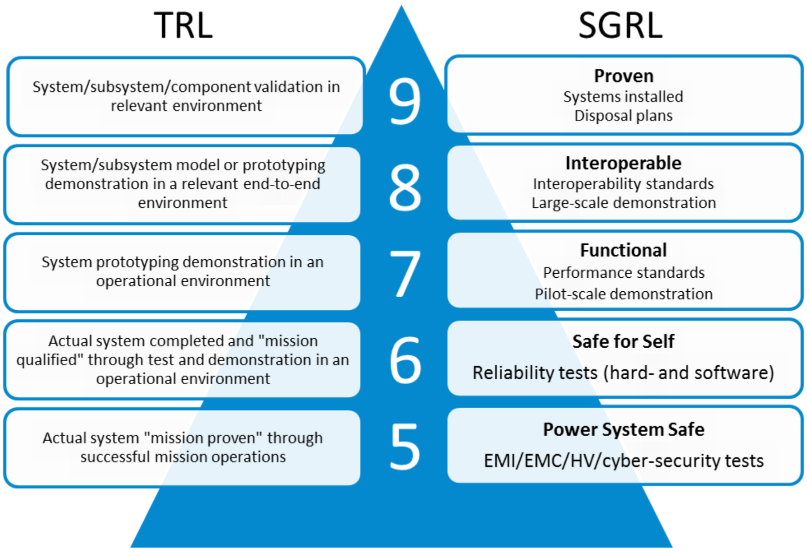


Abbildung 3: Gegenüberstellung von Technologie Readiness Level (TRL) zu Smart-Grid Readiness Level (SGRL)

Im nächsten Schritt wurde die Bewertung der Technologien um die Möglichkeit der Integration in Smart-Grids, wie in Abbildung 3 dargestellt, erweitert. Das Smart-Grid Readiness Level (SGRL) soll aufzeigen, wo Verbesserungsbedarf besteht, um die Anwendung der Technologien in zukünftigen Projekten verbessern zu können. Es zeigt sich, dass im Vergleich zum TRL die SGRL Werte i.d.R. ein Punkt geringer sind. Grund hierfür ist u.a. die höhere Komplexität und mehr Installations- und Wartungsaufwand bei der Kombination einzelner Technologien. Eine Ausnahme bildet Biomasse, welche technologisch zur Integration in Smart-Grids ausgereift ist. Generell jedoch sind auch die SGRL-Werte der einzelnen Technologien sehr hoch und diese damit für Smart-Grid Anwendungen bzw. Sektorkopplung prinzipiell einsatzfähig (siehe hierzu auch Abschnitt 2.2.2)

2.2.2 Sektorkopplung: Technologische Synergien und funktionale Interaktion verschiedener Energiesektoren

Ein optimiertes Gesamtenergiesystem nutzt bei der Kombination verschiedener Technologien gezielt deren Synergien und koppelt die Sektoren (Elektrizität, Mobilität und Wärme), um die Gesamteffizienz, Nachhaltigkeit und Integration erneuerbarer Energiequellen zu steigern. Ein häufiges Beispiel für Einfamilienhäuser ist die Erhöhung des Eigenverbrauchs von Strom aus Photovoltaik durch den zusätzlichen Einsatz von Wärmepumpe und Batteriespeicher. Der Überschuss an PV-Strom kann zur Deckung des Wärmebedarfs genutzt werden, indem die Wärmepumpe mit Strom versorgt oder ein batterieelektrisches Fahrzeug aufgeladen wird. Es kann auch ein stationäres Batteriespeichersystem zur Speicherung von elektrischer Energie eingesetzt werden um mit dieser zu einem späteren Zeitpunkt den Bedarf zu decken.

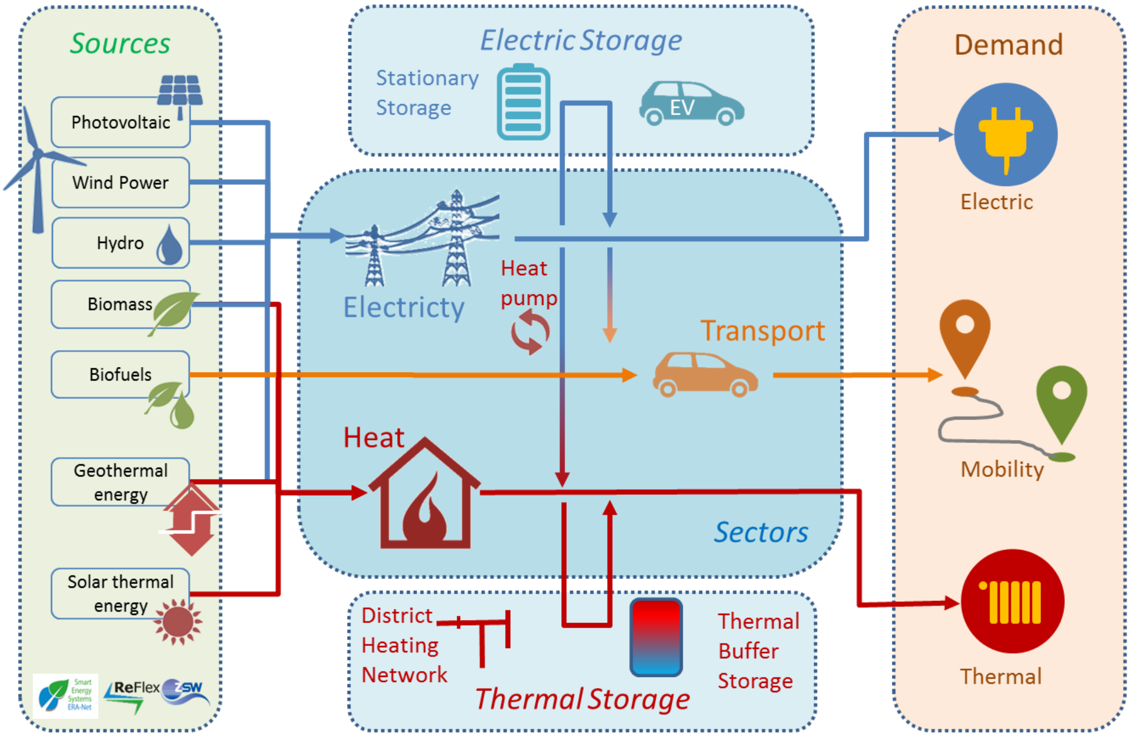
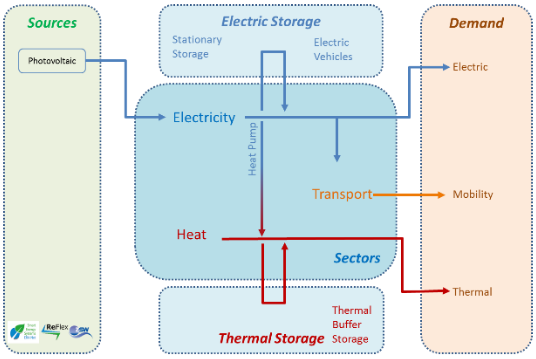


Abbildung 4: Sektorkopplung: Funktionale Interaktion verschiedener Energiesektoren (Elektrizität, Wärme, Mobilität) in den Pilotprojekten

Eine qualitative Übersicht mit den in den einzelnen Sektoren verwendeten Technologien (Strom- und Wärmeerzeugung, Mobilität, thermische und elektrische Speicher) und deren Sektorkopplung ist in *Abbildung 4* dargestellt. Beispielsweise kann Biomasse zur Stromerzeugung und/ oder Wärmeerzeugung genutzt werden. Mittels Speichertechnologien kann Energie zwischengespeichert und zeitlich verzögert, allerdings mit Verlusten, genutzt werden. Der produzierte Strom kann neben der direkten Nutzung im Stromsektor in der Mobilität oder zur Deckung des Wärmebedarfs verwendet werden. Diese Sektorkopplung ist auch umgekehrt aus dem Wärme- oder Mobilitätssektor (z.B. Geothermie-Kraftwerke oder Vehicle2Grid) möglich, wobei die Wirkungsgrade thermodynamisch bedingt deutlich geringer sind. In den Pilotprojekten wurde lediglich die Richtung vom Strom- zum Wärme- und Mobilitätssektor umgesetzt und deshalb in *Abbildung 4* ausschließlich dargestellt.

Um die einzelnen Pilotprojekte zu Anwendungsfällen (Use-Cases) zusammenfassen, wurden die Kernziele sowie untergeordnete Ziele der einzelnen Demosites analysiert. Diese werden im Folgenden für jedes einzelne Pilotprojekt dargestellt.

Biel-Benken (CH)



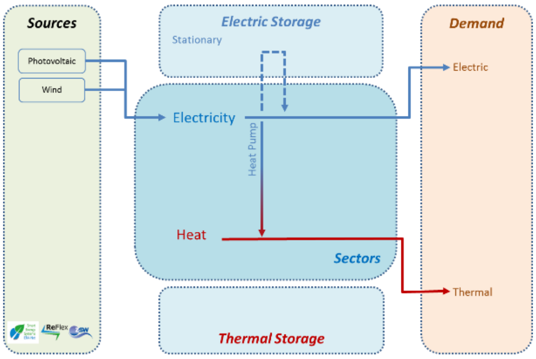
Lastmanagement

Ziel des Pilotprojekts in Biel-Benken war es Spitzenlasten durch Demand-Side-Management (DSM) zu vermeiden und die Spannung in einem Verteilnetzstrang durch fünf lokal in Haushalten installierte Steuergeräte zu stabilisieren, ohne den Komfort der Hausbewohner einzuschränken.

Gemessene Daten der einzelnen Häuser wurden ausgewertet, ein neuer Algorithmus getestet und neue Funktionen entwickelt.

- DSM-System reagiert auf lokale Spannung, steuert lokale Lasten und regelt damit indirekt die Spannung
- DSM zur Strompreisoptimierung
- DSM zur Reduzierung der Netzbelastung

Gotland (SE)



Erhöhung der Aufnahmekapazität, der Stromqualität und die Preise in Echtzeit

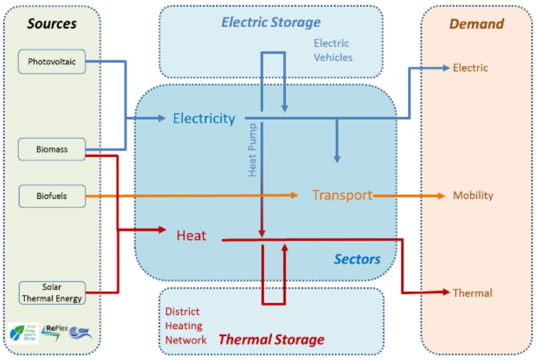
Ziel war die Erhöhung der Aufnahmekapazität des Verteilernetzes, zur Integration erneuerbare Energien. Außerdem die Aufrechterhaltung und Steigerung der Stromqualität im ländlichen Netz.

Getestet wurden Preisanreiz-Programme, um Kunden zu motivieren, große stromverbrauchende Geräte in Zeiten hoher Belastung mithilfe von Preissignalen auszuschalten.

- Steigerung der Aufnahmekapazität für erneuerbaren Strom im Verteilnetz durch aktive Lastverschiebung der Verbraucher
- Verbesserte Versorgungsqualität für den Kunden durch die Verringerung der Anzahl und Dauer von Stromausfällen

Motivierung von Haushalts- und Geschäftskunden auf dem Strommarkt aktiv zu werden

Güssing (AT)

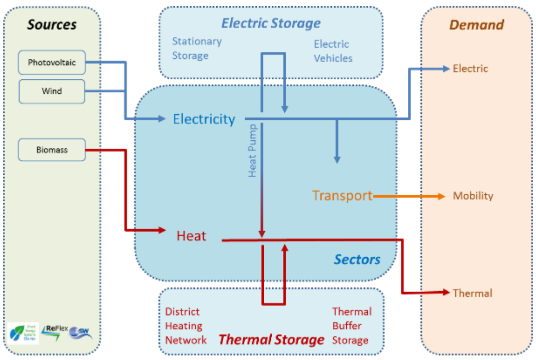


Mikro-Grid in definierter Modellregion

Das Hauptziel des Smart-Grids-Projekts in Güssing war die Überprüfung der Machbarkeit eines Mikronetzes mit einer optimierten Strom-Wärme-Kopplung in einer definierten städtischen Projektregion. In diesem Zusammenhang mussten die wirtschaftlichen, technischen, rechtlichen, sicherheitstechnischen und sozialen Rahmenbedingungen geklärt und definiert werden.

- Anpassung des Spannungsniveaus an die vorhandene Lastsituation im Netz
- Untersuchung der Integration von Strom-Speicher-Systemen in einem Mikronetz
- Untersuchung von Möglichkeiten für Demand-Side-Management bei Haushalten und Industrie in einer definierten Mikronetzregion

Hartberg (AT)

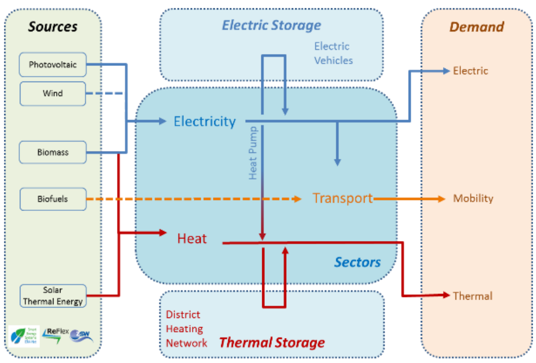


Gesamtheitliches innovatives Energiesystem

Vorrangiges Ziel war die Entwicklung und Erprobung eines innovativen, umfassenden und integrierten Energiesystems für Strom, Wärme und Kälte sowie deren Netze in der Stadt Hartberg.

- Integration erneuerbarer Energiequellen
- Integration von Speicherkapazitäten
- Bereitstellung neuer Systemdienstleistungen

Malmö (SE)

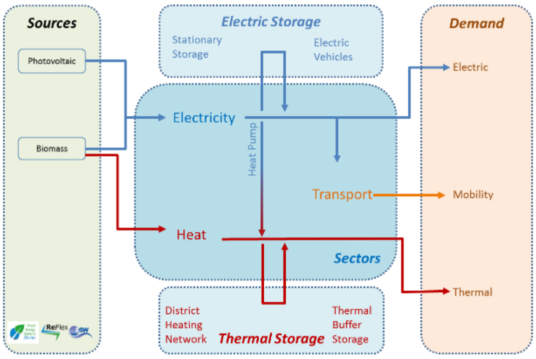


Klimafreundlichste Stadt

Die Stadt Malmö hat eine ehrgeizige Umweltagenda: Sie will die klimafreundlichste Stadt werden und eine gesicherte Stromversorgung mit erneuerbaren Energien gewährleisten. Eines der Ziele ist es, bis 2020 eine 100% auf erneuerbare und zurückgewonnene Wärme und Reststoffe basierende Energieversorgung im neu gebauten Stadtteil Hyllie zu erreichen.

- Integriertes System von Strom, Gas, Wärme und Kühlung
- Energieeffiziente Gebäude, als Teil eines Smart-Grids
- Nachhaltiger öffentlicher Verkehr (Gas, Strom)
- Klimafreundlicher Lebensstil der Bewohner
- Hyllie als Stadtteil, der eine weltweit führende, klimafreundliche Lösung demonstriert

Köstendorf (AT)

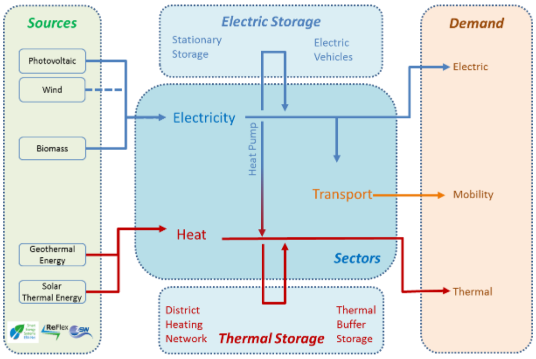


Spannungs-/ Blindleistungs-Steuerung und Integration von Heimspeichersystemen

Die Modellregion Salzburg testet in Köstendorf, wie man Gebäude optimiert, Elektroautos integriert und Netzstränge zentral über spannungsabhängige Blindleistungsregler regelt.

- Untersucht wird, wie Gebäude aktive Teilnehmer eines Smart-Grids sein können
- Erprobung von Schnittstellen zur Erstellung besserer Optimierungsalgorithmen und -strategien
- Analyse vorhandener Netzreserven und deren Nutzung

Wüstenrot (DE)



Plusenergiegemeinde

Bis 2020 will die Gemeinde Wüstenrot ihren Energiebedarf durch die Nutzung erneuerbarer Energiequellen wie Biomasse, Sonnenenergie, Windkraft und Geothermie auf einem Stadtgebiet von 3000 Hektar decken.

- Erhöhung des Eigenverbrauchs der Gemeinde
- Reduzierung der Netzbelastung
- Virtuelle Kraftwerksoptimierung (Bilanzierung und flächendeckende Auslastung)

2.2.3 Unterscheidung der Flexibilität

Durch die Integration fluktuierender Energiequellen ist die Möglichkeit einer Anpassung des Energieverbrauchs und die Zwischenspeicherung der Energie mit dem Ziel eine Dienstleistung im Energiesystem zu erbringen von zentraler Bedeutung. Diese Anpassung wird als Flexibilität bezeichnet. In der Literatur wird zwischen der Flexibilität der Leistung und der Flexibilität der Energie unterschieden, welche im Folgenden beschrieben werden (vgl. Abbildung 5). Die Flexibilität der Leistung hängt von der Leistungsfähigkeit einer Technologie ab, die Flexibilität der Energie von deren Dimensionierung. Wird die Flexibilität einer Technologie genutzt um Erzeugung oder Last auf einen anderen Zeitpunkt zu verschieben, spricht man auch von Verschiebungspotenzial. Die betrachteten Technologien weisen unterschiedliche Eigenschaften hinsichtlich Kapazität, Entladedauer und Leistungsrampe auf, die sie für bestimmte Einsatzmöglichkeiten qualifizieren

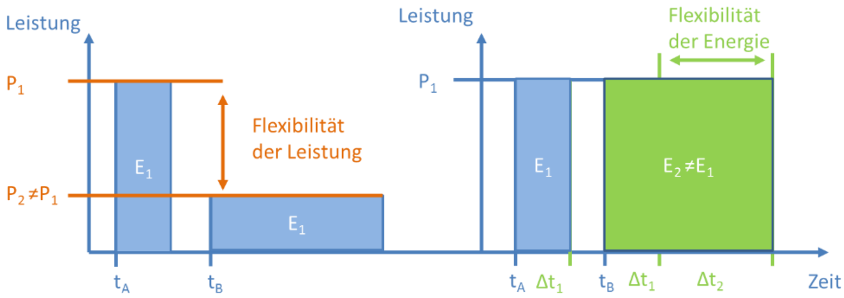


Abbildung 5: Unterscheidung der Flexibilitäten im Energiesektor in Flexibilität der Leistung (Leistung wird variiert), und Flexibilität der Energie (Energiemenge wird varriert). Beide Flexibilitäten können von einem Zeitpunkt A auf Zeitpunt B verschoben werden

1. Flexibilität der Leistung

Die Flexibilität der Leistung mit Dimension Zeitpunkt t und Leistung P ermöglicht es, dass zu jedem Zeitpunkt in einem Energiesystem Erzeugung und Verbrauch übereinstimmen (innerhalb von Sekunden oder Minuten). Zu den wichtigsten Systemdienstleistungen zählen die Frequenz- und Spannungshaltung und das Netzengpassmanagement. Wie in Abbildung 5 links dargestellt, wird die Leistung P der Technologie für diese Flexibilität variiert, die Energiemenge E bleibt gleich. Zusätzlich kann die Erzeugung bzw. die Last auf einem anderen Zeitpunkt verschoben werden.

Die Flexibilitätsoptionen werden eingesetzt, um:

- Spannungsqualität im gesamten Stromnetz und lokale Netzstabilität zu gewährleisten,
- Schwankungen im Stromnetz im Sekunden-/Minutenbereich mittels Engpassmanagement-Maßnahmen und Bereitstellung und Vorhaltung von Leistungsreserve (Regelleistung), insbesondere aufgrund des steigenden Anteil an volatiler Stromerzeugung durch Erneuerbare Energien, auszugleichen.

2. Flexibilität der Energie

Die Bilanz zwischen (Strom-)Erzeugung und Verbrauch muss über einen längeren Zeitraum Δt (Stunden, Tage oder Jahreszeiten) ausgeglichen werden, um Schwankungen und Unsicherheiten im gesamten Energiesystem ausgleichen zu können sowie die ambitionierten nationalen und europäischen Dekarbonisierungsziele zu erreichen. Hierfür werden Technologien benötigt, welche die Energiemenge E varrieren können, also eine Flexiblität der Energie innehaben (vgl. Abbildung 5 rechts). Auch diese Technologien könne zeitlich verschoben werden

Ziel der Flexibilität der Energie ist es,

- Schwankungen des Dargebots an Wind-und PV-Strom vor allem über längere Zeiträume auszugleichen,
- sicherzustellen, dass lokal erzeugte erneuerbare Energie für eine lokale Nutzung optimal eingesetzt wird,
- die Dekarbonisierung des Energiesystems über längere Zeiträume zu unterstützen.

Die eingesetzten Technologien in den ReFlex-Pilotprojekten weisen sowohl Flexibilitätspotential bzgl. der Leistung und/ oder der Energie auf. Ihr Verschiebepotential ist in Abbildung 6 dargestellt.

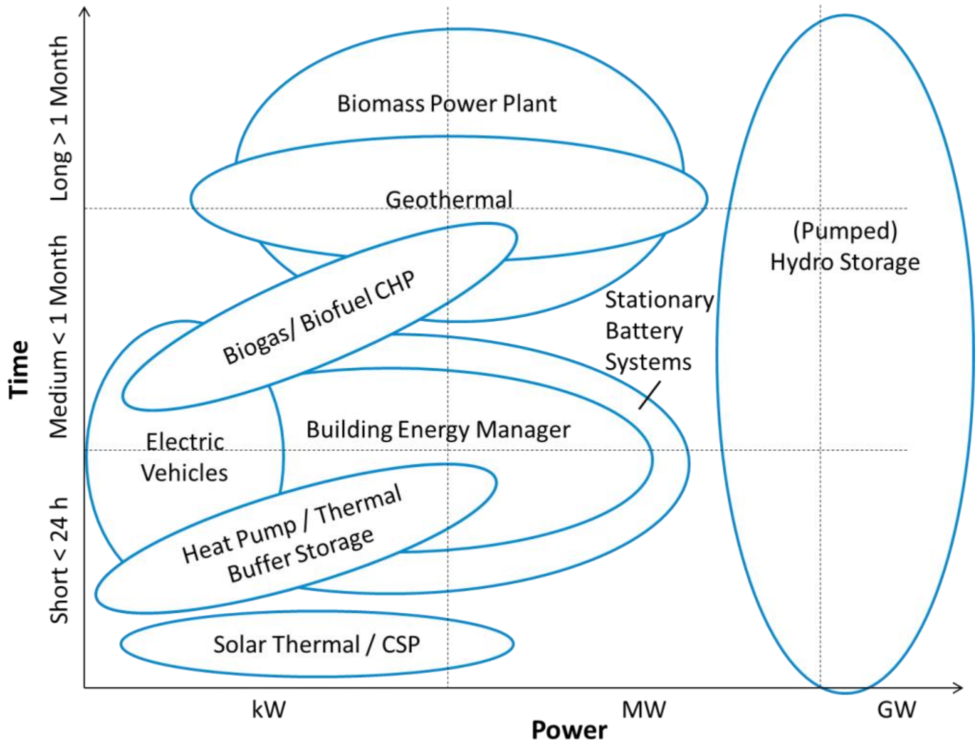


Abbildung 6: Leistung und zeitliches Verschiebepotential von Erzeugungsanlagen, Speichersystemen und Prozessen

Die in der Praxis eingesetzten Technologien zur Erzeugung und Speicherung elektrischer sowie thermischer Energie können hinsichtlich ihrer Leistungsbereiche, von klein (kW) bis groß (GW), der zeitliche Abhängigkeiten der Erzeugung und deren Flexibilitätspotential eingeteilt werden (vgl. Abbildung 6). Die Verschiebepotential elektrischer und thermischer Energie ist primär abhängig von der Energiequelle. Sonnen- und Windenergie sind stark skalierbar in ihrem Leistungsbereich und können in ihrer Leistung reduziert (Flexibilität der Leistung durch Teillast oder Ruhezustand) werden. Allerdings sind diese zeitlich nicht beeinflussbar und haben somit kein Verschiebungspotential (in Abbildung 6 würden sie sich entlang der waagrechten Koordinatenachse erstrecken). Erst in Verbindung mit Speichertechnologien ist Verschiebungspotential vorhanden. Biomassekraftwerke sind aufgrund des chemischen Energieträgers Biomasse über einen langen Zeitraum verschiebbar. Wegen ihrer Selbstentladung bzw. des hohen Bereitstellungsaufwands sind thermische und elektrische Energiespeicher nur kurz und mittelfristig verschiebbar. Lediglich Pumpspeicherkraftwerke oder Kavernenspeicher nutzen (potentielle und chemische) Energie, welche prinzipiell innerhalb des gesamten, hier abgebildeten, zeitlichen Verschiebungsbereichs vorgehalten und bei Bedarf kurzzeitig mit hoher Leistung abgerufen werden kann. Auch das Gasnetz kann als Energiespeicher über den gesamten zeitlichen Verschiebungsbereich betrachtet werden. In den ReFlex Pilotprojekten, fand ein Gasnetz jedoch keine nennenswerte Anwendung und wurde somit hier nicht weiter berücksichtigt.

2.2.4 Anwendungsfälle für Smart-Grid Lösungen

Für eine gute Übertragbarkeit der Pilotprojekte auf zukünftige Projekte wurden vier allgemeine Anwendungsfälle definiert. Hierzu wurde aufbauend auf der Analyse zu den eingesetzten Technologien und der Sektorkopplung in den Pilotprojekten (vgl. Abschnitt 2.2.1 und 2.2.2)die projektspezifischen Lösungen soweit möglich zusammengefasst.

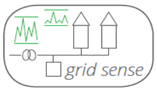
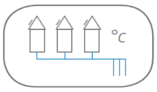
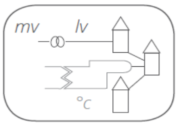
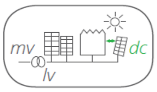
	Flexibility of Power	**Flexibility of Energy-Logistics**
Grid Management B2C with actively engaged energy end-user	Short-term voltage-stabilization in local electricity grid 	Shared use of local low temperature resources 
Load & Energy Management Services B2B without active engagement energy end-user	Load shifting for load-management of energy-utilities 	Energy Management for business parks 

Abbildung 7: Use-Case Übersicht

Die viel allgemeinen Anwendungsfälle wurden, wie in Abbildung 7 dargestellt, weiterhin nach der primär ermöglichten Flexibilität (vgl. Abschnitt 2.2.3) den zwei Kategorien Flexibilität der Leistung oder Flexibilität der Energie zugeteilt. In zweiten Schritt erfolgte die Einteilung, in Business-to-Business (B2B) und Business-to-Costumer (B2C) Lösungen, wobei nach den beteiligen Geschäftspartnern (Geschäftskunden oder private Kunden) unterschieden wurde. Somit ergeben sich jeweils ein Use-Cases zur Leistungsoptimierung für B2B und B2C und einer zur Optimierung der Energielogistik zwischen den jeweiligen Geschäftspartnern. Die Ableitung der vier Anwendungsfälle erfolgte in Absprache mit den Projektpartnern. Eine detaillierte Beschreibung aller Anwendungsfälle findet sich im ReFlex-Leitfaden (siehe Anhang).

Der technologische Teil (verwendete Technologien, Skalierbarkeit und Reproduzierbarkeit) aller Use-Cases wurde durch das ZSW im ReFlex-Leitfaden beschrieben (siehe Anhang).
Für die Beschreibung der Use-Cases wurden verschiedene Ansätze (IEC 62559-2; SGAM; Business, Mission und Service Modell Canvas) untersucht hinsichtlich Ihrer Eignung für das Ziel einen Leitfaden für interessierte Gemeinden und Kommunen zu erstellen. Als Testfall für die Beschreibungsansätze diente der Use-Case von Wüstenrot „Shared use of local low temperature resources".
Es zeigte sich, dass die genormte Beschreibung nach IEC 62259-2 nur von technisch versierten Personen nach langer Einarbeitung verständlich ist. Dies gilt gleichermaßen für die Darstellung mit Hilfe des Smart-Grid Architecture Model (SGAM). Mit dem „Business-, Mission- und Service-Modell"-Canvas konnten die Use-Cases präzise abgetrennt voneinander dargestellt werden, jedoch sind die Zusammenhänge zwischen den einzelnen Feldern nicht intuitiv und auch dieses System erfordert eine gewisse Einarbeitungszeit.

Die vom ZSW zusammengestellten Beschreibungsvorschläge, incl. Grafiken und Tabellen, wurden beim nationalen Projekttreffen der ReFlex-Partner im Dezember 2017 in Karlsruhe diskutiert. Alle Beschreibungssysteme IEC, SGAM und Canvas wurden als zu unverständlich für die Zielgruppe aus Gemeinderäten und Bürgermeistern eingestuft.
Im nächsten Schritt wurde ein allgemein verständliches Format als kompakte und einfach erklärende Beschreibung angestrebt. Das ZSW hat eine Vorlage aufbauend auf dem Use Case „Shared use of local low temperature resources“ erstellt und zusammen mit EIFER auf die anderen Use-Cases angewendet. Um den Vorteil der klaren Struktur und der guten Dokumentation der bereits vorhandenen Beschreibungssysteme zu nutzen, wurden Teile des SGAM sowie des Canvas-Models verwendet und an die Zielgruppe angepasst. Im Gegensatz zum SGAM kann bei dem Canvas-Model davon ausgegangen werden, dass selbst wenn es nicht bereits bekannt ist, es nach kurzer Einarbeitung von der Zielgruppe verstanden werden kann. Eine wichtige Erkenntnis aus dem Projekt ist die Berücksichtigung der Zielgruppe, insbesondre im interdisziplinären Forschugnsumfeld. Deshalb wurden zum besseren Verständnis der Zusammenhänge einfache Diagramme eingesetzt. Die Use Cases wurden zur besseren Übertragbarkeit allgemeingültig formuliert und mit deren beispielhaften Umsetzung in den jeweiligen Pilotprojekten vervollständigt. Auch technologische, wirtschaftliche, soziale und Umweltaspekte wurden im Leitfaden berücksichtigt und eingearbeitet.

2.3 AP2 - ReflexBox Simulationstool

Ausgehend von einer Skizze der wichtigsten Technologieparameter, wurde ab 2017 ein ReFlex-Simulationstool entwickelt und am Beispiel der Demo-Site von Wüstenrot und Biel-Benken getestet. Das Tool nutzt die von EIFER entwickelten Modelle (Technologie & Grid) sowie die bei den Demo-Sites erhobenen Daten. Die ReFlex-Projektpartner ZSW und SUPSI stellten zudem eigene Simulationsdaten zur Verfügung. Die ersten Simulationsergebnisse wurden beim CoP Workshop in Malmö mit Experten und Interessengruppen diskutiert. Die endgültige Version des Simulationstools (ReflexBox) wurde während der ReFlex-Abschlusskonferenz im Februar 2019 einem breiteren Publikum vorgestellt.

Das Tool hilft den an Smart-Grid-Projekten interessierten Entscheidungsträgern helfen, die Funktionsweise von Energiesystemen und das Flexibilitätspotenzial der simulierten Energiesysteme besser zu verstehen. Mit der ReflexBox können Energiesysteme bestehend aus einzelnen Einfamilienhäusern in einem Wohnviertel in einem Verteilernetz abgebildet werden und weiterhin, auf Basis des Referenzprojektes in Biel-Benken, Schweiz, an unterschiedliche Standorte in Europa repliziert und auf eine gewünschte Größe skaliert werden. Eine detaillierte Beschreibung ders ReFlexBox Simulationstool erfolgt in Abschnitt 5.

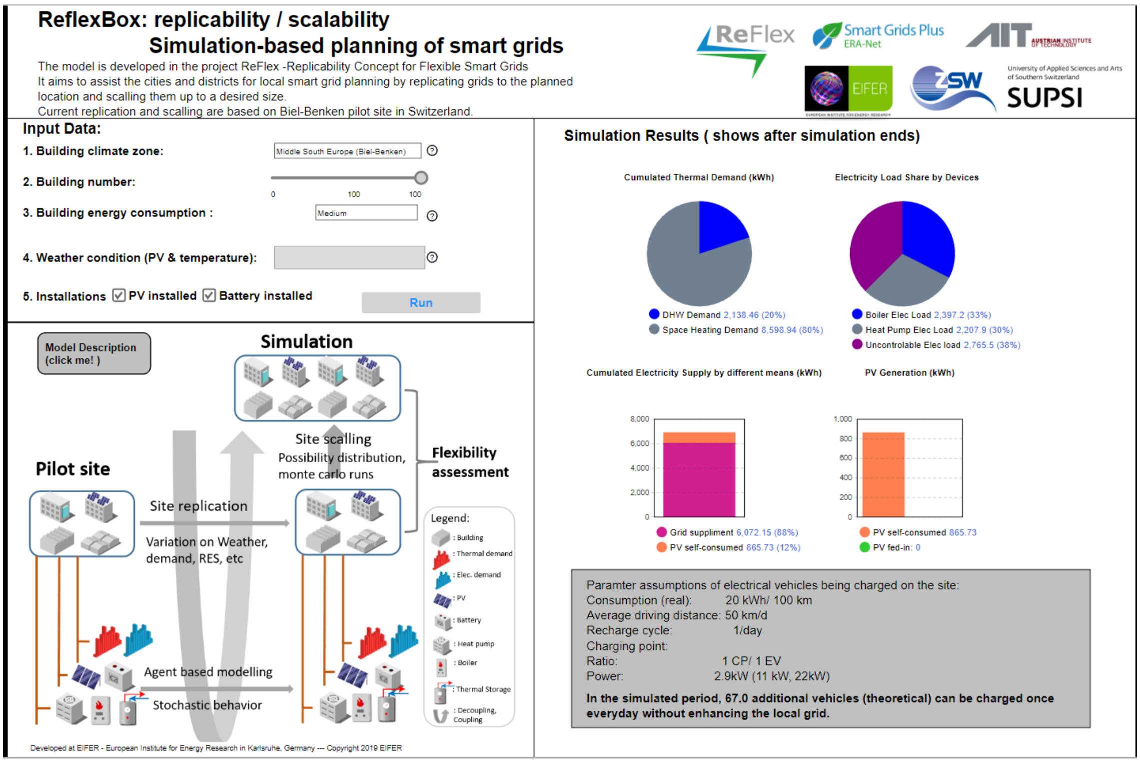


Abbildung 8: Benutzeroberfläche der „ReflexBox“

Eine Demoversion ermöglicht es, zwei voreingestellte Fälle zu simulieren. Sie ist unter folgendem Link abrufbar:

https://bit.ly/2GcMXZJ

Eine volle Version erlaubt dem Benutzer, das Setup anzupassen und an andere Orte zu replizieren. Diese ist unter folgendem Link erreichbar:

https://bit.ly/2Ht7YyJ.

2.4 AP3 - ReFlex Demo-Besuche vor Ort

Basierend auf Interviews mit den ReFlexDemo-Site-Partnern, wurde ein Konzept für Besuche vor Ort (sogenannte Site-Visits), Wissensaustausch und gegenseitiges Lernen zwischen relevanten Interessengruppen entwickelt.

Nach dem ersten Besuch des Demonstrationsprojekts in Hartberg, Österreich, von 23. bis 24. November 2016, besuchte das ReFlex-Projektteam vom 25. bis 26. Januar 2017 das Powergrid-Demonstrationsgelände in Biel-Benken, Schweiz. Während des zweitägigen Besuchs konnte sich das ReFlex-Team über den von der Schweizerischen Fachhochschule SUPSI in Zusammenarbeit mit den Energieversorgungsunternehmen EBM und Alpiq, einem führenden Schweizer Strom- und Energiedienstleister, entwickelten Regelalgorithmus GridSense informieren. Die GridSense-Technologie (ein vollständig dezentrales Energiemanagementsystem) ist in vier Wohnhäusern in Biel-Benken installiert und optimiert den Betrieb von steuerbaren Lasten. Die betriebswirtschaftlichen Aspekte sind bei diesem Pilotprojekt sehr wichtig, insbesondere wenn es um die Skalierung der Industrielösung und die schrittweise Markteinführung nach der Testphase geht.

Darüber hinaus fand vom 26. bis 27. Juni 2017 der Demo-Standortbesuch in Salzburg, Österreich, statt. Im Mittelpunkt standen die Smart-Grid-Modellregion Salzburg und die Kombination verschiedener Smart-Grid-Anwendungen zu einem integrierten System für eine ländlich geprägte Gemeinde Köstendorf. Neben der Demonstration technologischer Lösungen für reale Netzprobleme, spielte die Akzeptanz und Benutzerfreundlichkeit des Systems für die Kunden eine zentrale Rolle. Die Teilnehmer besuchten die Modellgemeinde Köstendorf mit einem starken Fokus auf Niederspannungsnetzanwendungen intelligenter Technologien.

Der von 4ward Energy, der Elektro Güssing GmbH und dem AIT organisierte Standortbesuch in Güssing (22.-23. März 2018) gab Einblicke in Feldversuche in Strem und Güssing, zwei Gemeinden des Regionalverbandes ökoEnergieland Burgenland. Die Ergebnisse des Microgrid-Projekts in Güssing, und der Projekte 3Smart und SHAR-Q wurden dabei vorgestellt und mit den Teilnehmern diskutiert.

2.5 AP3 - CoP Workshops

Gemäß dem Projektplan wurden drei Community of Practice (CoP) Workshops von den lokalen ReFlex-Partnern in Zusammenarbeit mit dem AIT und EIFER (in Wüstenrot in Deutschland vom 13. bis 15. März 2017, in Malmö in Schweden vom 18. bis 20. Oktober 2017 und in Lausanne in der Schweiz vom 4. bis 6. Juni 2018) durchgeführt, um einen länderübergreifenden und intensiven Wissensaustausch zwischen Smart-Grid-Demoregionen als wesentlichen Projektbestandteil zu etablieren und aufrechtzuerhalten. Dabei wurden die Lehren aus den Feldversuchsexperimenten, einschließlich Querschnittsthemen (Marktplatz, Interessenvertreter und Technologie), diskutiert und Folgeforschungsfragen identifiziert. Das ZSW organisierte den ersten CoP in Wüstenrot in Zusammenarbeit mit seinen Unterauftragnehmern Gemeinde Wüstenrot und der HFT. Weiterhin brachte das ZSW auf allen CoPs externe Expertise aus der Industrie durch AVAT (Unterauftragnehmer) und aus der Wissenschaftlern durch internationale Kontakte (Hochschule Basel, Schweiz und Universität Utrecht, Niederlande) ein.

Basierend auf dem Feedback, das während dieser Veranstaltungen gesammelt wurde, und der vom ReFlex-Forschungsteam durchgeführten Recherchen, wurden die wichtigsten Hindernisse für die Replikation und Skalierbarkeit ermittelt und nach ihrer Bedeutung eingestuft. Die Ergebnisse sind in der folgenden Abbildung dargestellt.

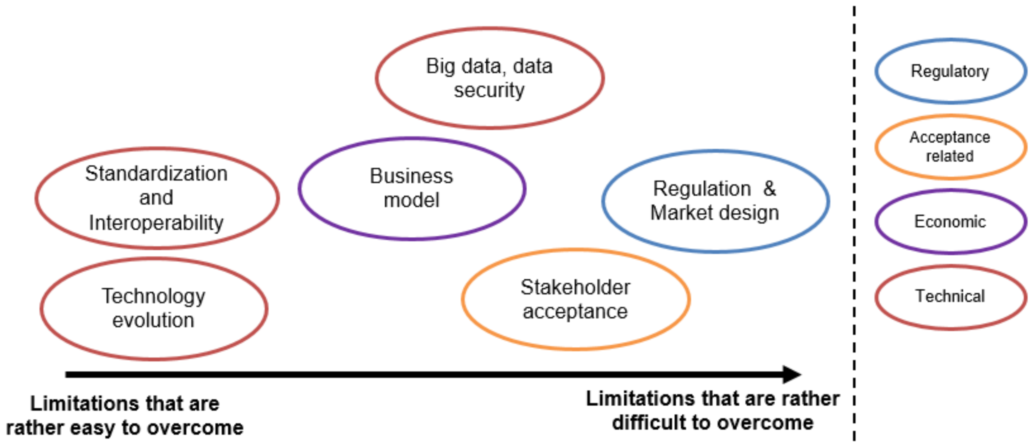


Abbildung 9: Eigene Darstellung basierend auf [Sigrist et al., 2016]

2.5.1 Marktregulierung und Marktdesign

Die Marktregulierung der Energieversorgungsnetze gilt als eines der Haupthindernisse für innovative Smart-Grid-Lösungen. Die Anreizregulierung (Regulierung von ÜNB und VNB-Einnahmen) fordert Netzbetreiber auf, die effizientesten Lösungen für den Netzbetrieb zu wählen. Innovative Lösungen wie Speichersysteme oder Smart Controller weisen derzeit höhere Investitionen auf und/oder können gegenüber den zuständigen Netzbehörden (z.B. Bundesnetzagentur) nicht geltend gemacht werden. Deshalb bevorzugen Netzbetreiber Investitionen in Netzausbaumaßnahmen gegenüber der Implementierung und Erprobung von Smart-Grid-Lösungen.

Die Projektpartner empfehlen auch, den Regulierungsrahmen anzupassen, um Investitionen in Lösungen zu fördern, die Flexibilität für das Netz oder das Energiesystem als Ganzes bieten. Das von der EU-Kommission im November 2016 vorgestellte Clean Energy Package wird Raum für neue Entwicklungen im Bereich der Selbstversorger und Endverbraucherlösungen bieten.

2.5.2 Gesellschaftliche Akzeptanz, Datenschutz und Datensicherheit

Transparenz ist ein Schlüsselelement, um das Vertrauen der Kunden zu gewinnen. Die Nutzer sind in der Regel weniger um Sicherheit und Datenschutz besorgt, wenn der Nutzen klar und sichtbar ist. Es wurde festgestellt, dass die Wahrnehmungen der Menschen von Land zu Land sehr unterschiedlich sind: das heißt, der Datenschutz und -sicherheit sind in Deutschland ein viel sensibleres Thema als z.B. in Schweden.

Um die Akzeptanz von Smart-Grid-Lösungen in der Öffentlichkeit zu erhöhen, schlugen die CoP-Teilnehmer zwei mögliche Handlungsoptionen vor:

- Klare und detaillierte Kommunikation über die Smart-Grid-Lösungen und die damit verbundenen Dienstleistungen,
- Menschen sollten die Möglichkeit haben, diese Lösungen zu erproben, um sich selbst ein Bild zu machen.

2.5.3 Geschäftsmodelle

Die europäischen Energiemärkte sind aufgrund von Trends wie der Digitalisierung, und dem rasanten Wachstum der erneuerbaren Energien, im Wandel. Laut Projektpartner und Teilnehmer der CoPs, wird sich das institutionelle Rahmen in den nächsten 10-30 Jahren weiterentwickeln. Es wird erwartet, dass Kooperationsgeschäftsmodelle, die auf kooperativen Lösungen oder Fusionen basieren, an Bedeutung gewinnen werden.

Die CoP-Teilnehmer berichteten, dass nur wenige Pilotprojekte einen Mehrwert schaffen konnten. Dafür gibt es verschiedene Gründe: der Rechtsrahmen wird durch Innovationen im Technologie- und Kommunikationsbereich überholt; es fehlen noch innovative Preissysteme (dynamische Tarife) und es gibt Kooperationsschwierigkeiten zwischen Energieakteuren aufgrund der aktuellen Marktgestaltung (Unbundling – Entflechtung die das Ziel verfolgt, die Unabhängigkeit des Netzbetreibers von anderen Tätigkeitsbereichen der Energieversorgung sicherzustellen).

2.5.4 Standardisierung und Interoperabilität

Fehlende Standards für die Steuerung von steuerbaren Lasten sind momentan eine der großen Herausforderung für die Verbreitung von Demand-Side-Management Lösungen. Die Harmonisierung durch einheitliche Einführung von europäischen Normen würde zu erheblichen Kosteneinsparungen führen und die Replikation und Skalierung von Smart-Grid-Projekten in den EU-Mitgliedstaaten fördern.

Blockchain und die damit verbundenen Sicherheits- und Energiefragen wurden während der Besuche und Workshops vor Ort intensiv diskutiert. Blockchain gilt als eine vielversprechende Technologie, die die Teilnahme kleiner Akteure am Energiemarkt ermöglichen kann. Allerdings muss es noch unter realen Bedingungen getestet und validiert werden, bevor es vollständig zur Markteinführung bereit ist. Der Erfolg dieses Buchführungssystems beruht auf der Unterstützung der Hardwarehersteller sowie einer breiten öffentlichen Akzeptanz.

2.6 AP4 - ReFlex Leitfaden & Policy Brief

Es wurden Leitlinien ausgearbeitet und in Form eines Leitfadens gebracht, um die Demo-Regionen und die breitere Gruppe der europäischen Smar-Grid-Stakeholder bei der Umsetzung und Weiterentwicklung ihrer Smart-Grid-Initiativen und Replikationsprojekte zu unterstützen. Die Aufbereitung und diverse Beiträge erfolgte hierbei durch EIFER und ZSW und können Abschnitt 2.2 entnommen werden.

Der erste Teil des Leitfadens beschreibt vier typische Use-Cases (Anwendungsfälle), basierend auf Beispielen aus den acht Demo-Standorten des ReFlex-Projekts. Die Anwendungsfälle befassen sich mit den folgenden zwei Systemdienstleistungen:

- dem kurzfristigen Ausgleich der Abweichungen zwischen Erzeugung und Verbrauch z.B. mit Regelenergie,

- dem mittel- bis langfristigen (saisonalen) Ausgleich von Erzeugung und Verbrauch mittels Smart-Grid basierte Flexibilitätsoptionen.

Der zweite Teil des Leitfadens enthält eine Checkliste und eine Toolbox, die Interessengruppen bei der Planung, Entwicklung und Implementierung von Use-Cases in Replikationsprojekten unterstützen. Darüber hinaus wurde eine Entscheidungshilfe zur Replizierbarkeit von Smart-Grid Projekten für politische Entscheidungsträger auf nationaler und europäischer Ebene erstellt. Der in Englisch verfasste ReFlex Leitfaden ist im Anhang beigefügt.

3 Nutzen und Verwertbarkeit der Ergebnisse

Das ZSW und EIFER streben eine Weiterverwertung der Ergebnisse des Vorhabens in Folgeprojekten der ERA-Net Smart-Grids Plus und ERA-Net Smart Energy Systems Initiativen sowie in nationalen Forschungsprojekten an.

So hat das ZSW im Jahr 2016 zusammen mit Partnern aus Industrie, Energiedienstleistern und Forschungsinstituten der Plattform zur Förderung intelligenter Energienetze „SmartGrids BW“ die Vorhabenskizze C/sells im Rahmen des Förderprogramms „Schaufenster intelligente Energie - Digital Agenda für die Energiewende“ (SINTEG) des BMWi (Volumen 80 Mio€) eingereicht. Das Projekt wurde angenommen und offiziell am ersten Januar 2017 gestartet. Durchgeführt wird C/sells Vorhaben als dezentrales Großprojekt von 41 Partnern aus Forschung, dem kommunalen Umfeld sowie der Industrie und Wirtschaft. Weiterhin sind 28 Partner assoziiert. Das Projekt erprobt und erforscht die Digitalisierung der Netzinfrastruktur mit den Schwerpunkten dezentraler Energieerzeugung und Photovoltaik [C/sells, 2019].

EIFER hat 2018 zusammen mit Partner aus Österreich, Frankreich und Belgien die Projektskizze CRESTRIA im Rahmen des ersten Aufrufs der ERA-Net Smart Energy Systems Initiative eingereicht. Ziel des Vorhabens war es, Städte und Regionen bei der Umsetzung innovativer Energielösungen zu unterstützen - auf der Grundlage eines überregionalen Wissensaustauschs in der Form einer Community of Practice. CRESTRIA sollte u.a. auf den Ergebnissen des Forschungsprojekts ReFlex aufbauen und das ReFlex-Simulationstool weiter verwerten. Leider wurde der Antrag abgelehnt.

EIFER nimmt seit 2018 am Projekt SoLAR teil, das vom Land Baden-Württemberg gefördert wird und demonstriert, wie Strom aus Sonne, Wind und Wasser in einer Liegenschaft in Allensbach am Bodensee günstig und sicher gespeichert und genutzt werden kann [UM BW, 2018]. EIFER ist in diesem Projekt an der Entwicklung eines virtuellen Demonstrators als digitaler Zwilling des Multi-Energiesystems der Liegenschaft beteiligt. Dieser virtuelle Demonstrator wird das Projekt während seiner gesamten Laufzeit begleiten und erste Machbarkeitsergebnisse zur weiteren Extrapolationsstudien liefern. Somit können Netzsicherheitsmaßnahmen wie z.B. Resilienztests oder eine Netztrennung, die unter realen Bedingungen noch nicht vollständig getestet werden können, im Modell nachgebildet und untersucht werden.

4 Forschungsergebnisse anderer Stellen

- [Rodriguez-Calvo et al., 2018]

Dieser Artikel beschreibt bestehende Ansätze und Vorschläge für die Analyse der Skalierbarkeit und Replizierbarkeit (ASR) von Smart-Grid-Lösungen und beschreibt einige europäische Forschungs- und Demonstrationsprojekte. Kern der ASR-Methodik ist die technische Analyse auf der Grundlage von Simulationen, mit denen die Auswirkungen der Implementierungen von Smart-Grids Lösungen quantifiziert werden. Darüber hinaus beinhaltet die Methodik auch die Analyse von wirtschaftlichen, regulatorischen und sozialen Aspekten, um Treiber und Hindernisse für die Skalierbarkeit und Replizierbarkeit von Smart-Grid-Projekten zu identifizieren. Die Autoren haben herausgefunden, dass das Potenzial für Skalierbarkeit und Replizierbarkeit von Netzautomatisierungslösungen stark verbunden ist mit der Bereitschaft der Verbraucher, für eine höhere Netzzuverlässigkeit zu bezahlen. Die Autoren haben ebenfalls festgestellt, dass die Unterschiede bei den Anreizen zur Erhöhung der Zuverlässigkeit der Stromnetze in europäischen Ländern, das Potenzial des Hochskalierens intelligenter Netzlösungen stark einschränken können.

- [Sigrist et al. , 2016]

In dieser Studie wurde die Skalierbarkeit und Replizierbarkeit von Smart-Grid-Projekten untersucht. Hierfür wurden technische, wirtschaftliche, regulatorische und akzeptanzbezogene Faktoren identifiziert, die die Skalierbarkeit und Replizierbarkeit beeinflussen. Diese Faktoren wurden auf der Grundlage einer eingehenden Literaturrecherche ausgewählt. Es zeichnet sich im Allgemeinen ab, dass technische, wirtschaftliche, regulatorische und akzeptanzbezogene Fragen gleich wichtig für die Skalierbarkeit eines Smart-Grid-Projektes sind, während regulatorische und akzeptanzbezogene Faktoren für die Replizierbarkeit eines Projektes eine größere Bedeutung aufweisen als zum Beispiel technische Faktoren. Nach Ansicht der Autoren der Studie, sind die Barrieren für die Replizierbarkeit und Skalierbarkeit von Smart-Grid-Projektebn meistens auf externe Faktoren wie Regulierung, Standardisierung und Marktdesign zurückzuführen, auf die die Projektpartner in der Regel wenig Einfluss haben.

- [Le Baut, 2018]

Dieser Bericht wurde im Rahmen des Integrid-Projekts erstellt. Im Rahmen dieses Projekts werden Smart-Grid-Technologien in Demonstratoren in Portugal, Slowenien und Schweden implementiert und getestet. Um zu vermeiden, dass diese Experimente lokal bleiben, werden Treiber und Hindernisse für die Verbreitung der eingesetzten Technologien untersucht. Die Methodik zur Skalierbarkeits- und Replizierbarkeitsanalyse ist in die folgenden Bereiche unterteilt:

1. Funktionsorientierte Analyse
2. IKT orientierte Analyse
3. Wirtschaftsanalyse
4. Regulatorische Analyse.

Die Methodik wurde für 12 verschieden Use Cases angewendet (siehe die nachfolgende Abbildung). Ziel dieser Evaluierung ist es, ein möglichst genaues Verständnis der einzelnen Use Cases zu bekommen und zu entscheiden, ob eine erweiterte Analyse (quantitativ oder quantitativ) oder gar keine Analyse in jedem der 4 Bereiche durchgeführt werden soll. Diese Bewertung zielt ebenfalls darauf ab, die wichtigsten Faktoren in Hinblick auf Skalierbarkeit und die Replizierbarkeit zu untersuchen. Dies soll letztendlich dazu beitragen, erfolgsversprechende Geschäftsmodelle zu identifizieren.

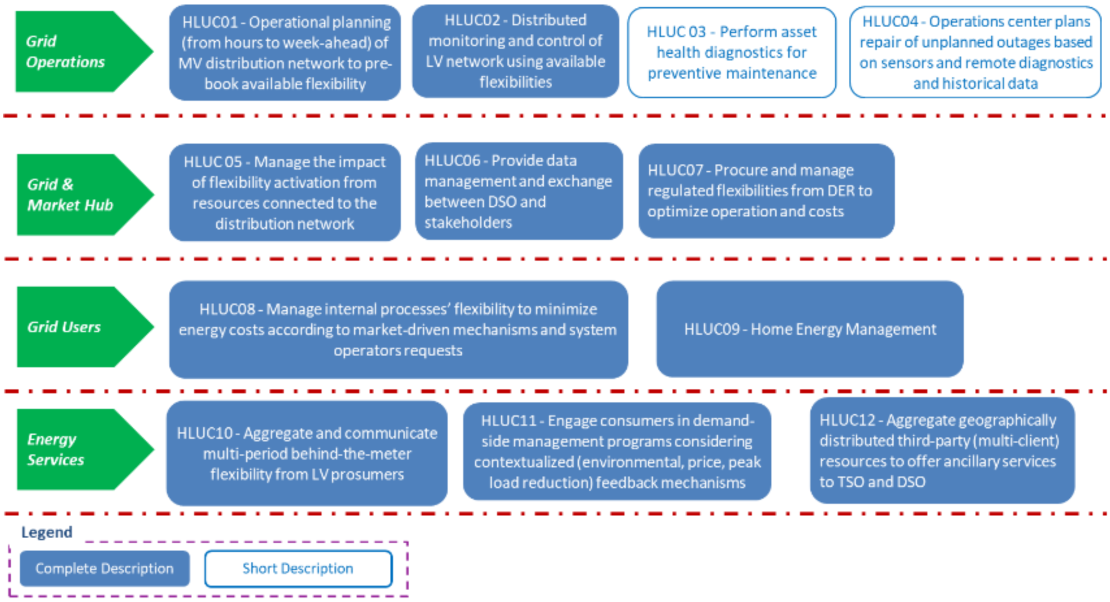


Abbildung 10: Übersicht über die 12 Use-Cases des Integrid-Projektes [Le Baut, 2018]

5 Detailierte Beschreibung des ReflexBox Simulationstools

Das Tool "ReflexBox" wurde von den drei ReFlex Projetpartnern EIFER, SUPSI und ZSW entwickelt, die sich auf einen koordinierten Simulationsansatz geeinigt haben. Das Tool simuliert den Betrieb eines Energiesystems auf Gebäude- und Quartiersebene und bewertet sein Flexibilitätspotenzial. Es kann auf dieser Weise Städte und Gemeinden bei der Planung ihres lokalen Smart-Grids unterstütztzen, indem es Netze am geplanten Standort repliziert und auf die gewünschte Größe skaliert.

Das Simulationsmodel stellt ein Wohnviertel dar bestehend aus Einfamilienhäusern. Jedes simulierte Gebäude ist mit einer Wärmepumpe und einem Warmwasserspeicher zur Raumheizung, einem Elektroboiler und einem Wassertank zur Warmwasserversorgung sowie einem PV- und Batteriesystem zur Stromversorgung ausgestattet.

Das Flexibilitätspotenzial eines Netzes ist definiert als eine Leistungsanpassung, die über einen längeren Zeitraum gehalten wird, ohne den Komfortniveau in den Gebäuden zu beeinflussen. Das Flexibilitätspotenzial des replizierten und skalierten Systems wird in der Simulation quantifiziert und veranschaulicht durch die Anzahl der Elektrofahrzeuge, die ohne Ausbau des vorhandenen Energiesystems zusätzlich geladen werden können.

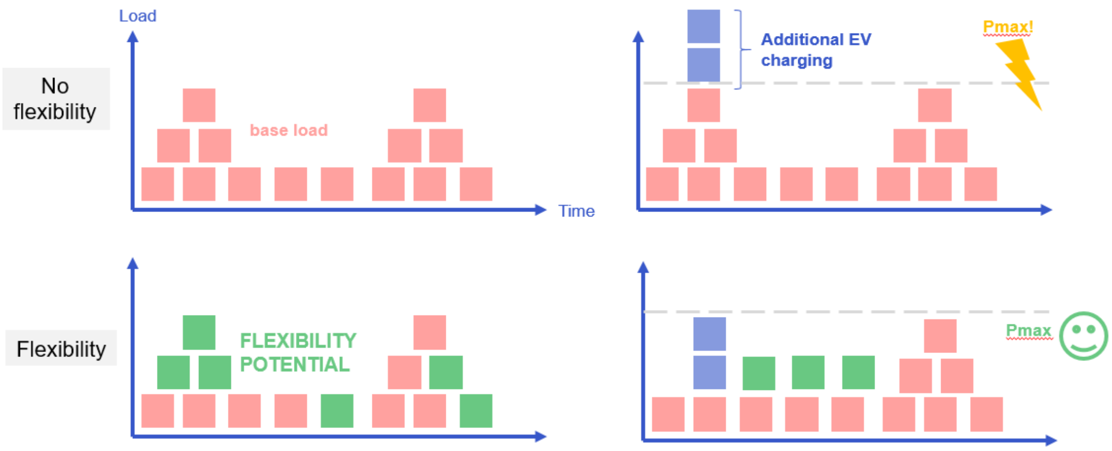


Abbildung 11: Veranschaulichung der Vorteile der Flexibilität für das Energiesystem

Eine Demoversion, womit zwei vordefinierte Fälle simuliert werden können, ist unter folgendem Link abrufbar: *https://bit.ly/2GcMXZJ*

Eine Vollversion erlaubt es, das Setup anzupassen und an andere Standorte zu replizieren. Sie kann unter folgendem Link heruntergeladen werden: *https://bit.ly/2Ht7YyJ*

5.1 Benutzeroberfläche

Die folgende Abbildung zeigt die Benutzeroberfläche des Tools „ReFlexbox“. Die Eingabeparameter können in der oberen Ecke links geändert werden und die Modellarchitektur ist direkt darunter dargestellt. Auf der rechten Seite werden die Ergebnisse angezeigt, sobald die Simulation abgeschlossen ist.

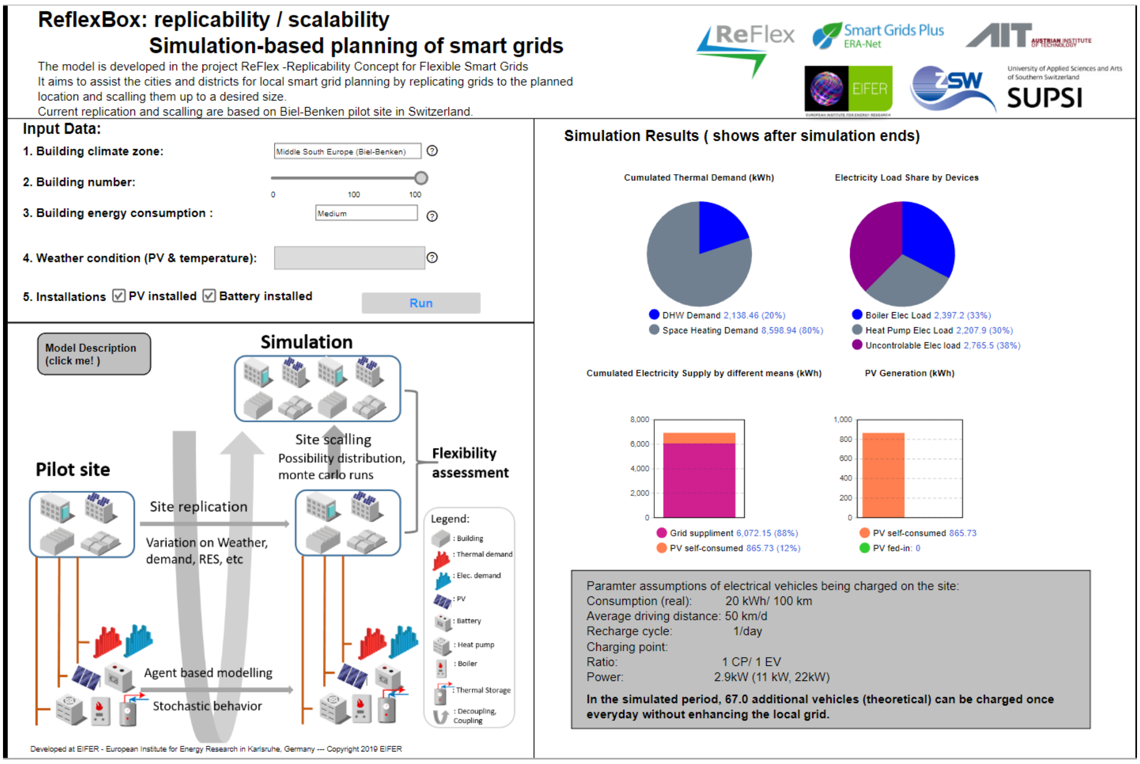


Abbildung 12: Benutzeroberfläche der ReFlexbox

Der Benutzer kann zwischen vier Klimazonen wählen, die im Tool implementiert sind, darunter Mittel-Südeuropa, Mittel-Nordeuropa, Mittel-Osteuropa und Nordeuropa. Die nachgebildeten Wetterbedingungen sind jeweils die der Städten Biel-Benken in der Schweiz, Malmö in Schweden, Warschau in Polen und Berlin in Deutschland.

Wenn die Option "Benutzerdefinierter Ort" ausgekreuzt ist, kann der Benutzer eine ausgewählte Wetterdatei im Format TMY (.tm2) hochladen. Daten für andere Standorte können aus der Meteonorm-Datenbank https://meteonorm.com/ entnommen werden.

Der Benutzer kann die Anzahl der zu simulierenden Gebäude wählen. Die Referenz für den gebäudebezogenen thermischen Energieverbrauch ist der durchschnittliche simulierte Wärmeverbrauch eines 100-Häuser-Viertels in Biel-Benken, was 6470 kWh/Jahr/Haus entspricht. Fünf verschieden Verbrauchsstufen können eingestellt werden:

- "Sehr hoch" entspricht einem 20% höheren Verbrauch als bei dem Biel-Benken Fallbeispiel,
- "Hoch": 10% höher,
- "Mittel": gleich,
- "Niedrig": 10% niedriger
- "sehr niedrig": 20% niedriger

Der Benutzer hat auch die Möglichkeit, durch Aktivieren oder Deaktivieren des Kontrollkästchens die PV- und Batterieanlagen bei der Simulation zu berücksichtigen.

5.2 Modellierungsverfahren

Für die Simulation von Energiesystemen wird ein hybrider Multimethodenansatz verwendet, bei dem drei Hauptmethoden angewendet werden: System Dynamics (SD), Discrete Event (DE) Modellierung und Agentenbasierte Modellierung (ABM). Diese drei Modellierungsmethoden ermöglichen eine relativ umfassende Darstellung komplexer Systeme.

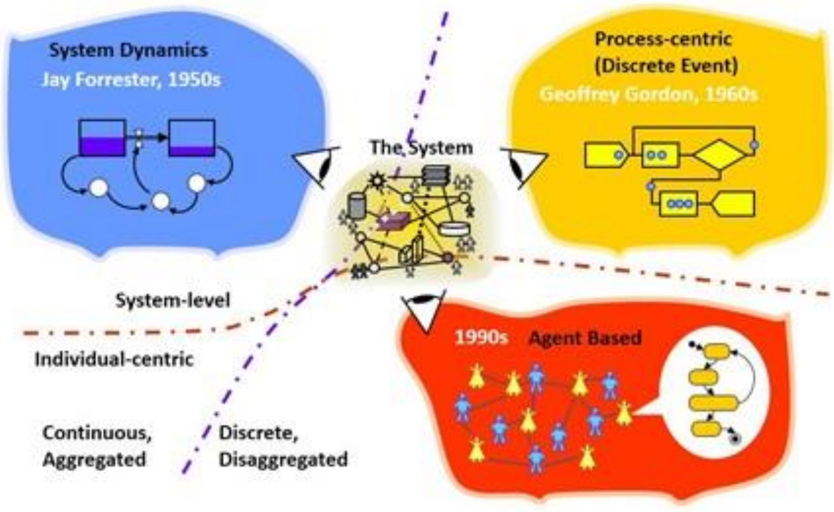


Abbildung 13: Reflex Box - verwendete hybride Modellierungsmethode

5.3 Evaluierung der Replizierbarkeit und Skalierbarkeit

Ermittlung des Gebäudeenergiebedarfs

Das Simulationstool ermittelt den Energiebedarf der zu simulierenden Gebäuden basierend auf Simulationsergebnissen vom ReFlex-Projektpartner SUPSI. Die detaillierten Annahmen zum Raumwärmebedarf, Warmwasserbedarf und Strombedarf werden ebenfalls auf dieser Weise generiert.

Festlegung der Konfiguration des zu simulierenden Energiesystems

Das Simulationstool bestimmt die Anzahl der Bewohner in einem Gebäude gemäß einer Wahrscheinlichkeitsverteilung auf der Grundlage von Bevölkerungsstatistiken. Nachfolgend wird die erforderliche Wassertankgröße für die Warmwasserbereitstellung entsprechend der ermittelten Anzahl der Bewohner bestimmt. Darüber hinaus bestimmt das Tool die Leistung der Elektroboiler, unter der Annahme, dass der Wassertank in 1 bis 3 Stunden vollständig geladen werden muss.

Das Tool fügt dem Modell Wärmepumpen für die Raumheizung hinzu, indem es thermische Gleichungen basierend auf Parametern wie Wärmewiderstand und Innentemperatur verwendet. Das

Tool ergänzt das Modell auch um Warmwasserspeicher sowie PV-Systeme und Batterien. Das Volumen der Wassertanks liegt zwischen 300 und 700 Litern. Die Leistung der PV-Anlagen bewegt sich zwischen 5 und 10 kW, während die Batteriekapazität dem 2-3fachen der PV-Anlage entspricht.

Regeln für den Betrieb des Energiesystems

Die Strategie für den Betrieb des simulierten Energiesystems folgt den folgenden Regeln:

Für den Wärmebedarf erzeugen Wärmepumpen und Elektroboiler Wärme, bis die angeschlossenen Speicher voll sind. Gleichzeitig entladen sich die Wasserspeicher, um den Wärmebedarf zu decken. Wärmepumpen und Boiler werden wieder eingeschaltet, wenn sie einen vordefinierten minimalen Ladezustand erreichen.

Der Strombedarf, der sich aus der Summe des Verbrauchs von nicht steuerbaren Lasten sowie Wärmepumpen und Elektroboilers ergibt, wird zunächst durch die PV-Erzeugung abgedeckt. Liegt keine ausreichende PV-Erzeugung zur Deckung des Strombedarfs vor, wird im zweiten Schritt die Batterie entladen und wenn diese Maßnahme nicht ausreicht, wird die erforderliche zusätzliche Energie aus dem Netz entnommen.

Bei überschüssiger PV-Erzeugung werden die Batterien bis zum Erreichen ihrer vollen Kapazität geladen und der anschließend erzeugte PV-Strom in das lokale Netz eingespeist.

Berechnung der Flexibilität des Energiesystems

Ein Flexibilitätsprodukt kann mit vier Merkmalen beschrieben werden, wie in der Abbildung 14 dargestellt: nach seiner Richtung (a): aufwärts oder abwärts; nach seiner Leistung (b) nach seiner Reaktionszeit (c) und nach der Dauer (d).

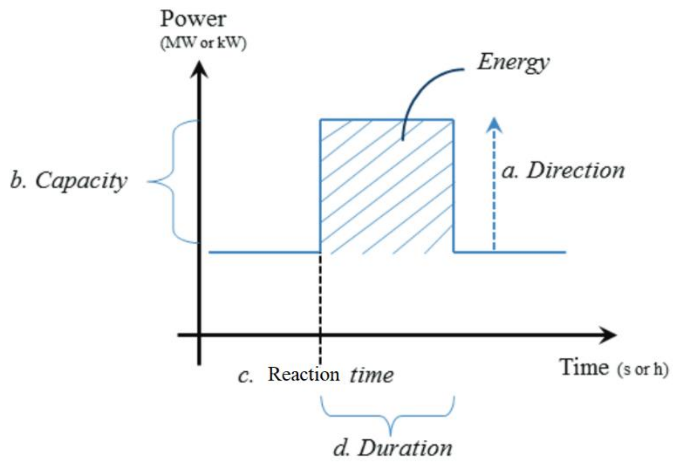


Abbildung 14: Hauptmerkmale eines Flexibilitätsprodukts

Schritte zur Berechnung des Flexibilitätspotenzials:

1. Für jede steuerbare Last (Wärmepumpe, Elektroboiler, Batterie), wird überprüft, ob sie ein- oder ausgeschaltet ist.
2. Für jede steuerbare Last, wird die Dauer t berechnet, in der die steuerbare Last ohne Komforteinbußen abgeschaltet oder eingeschaltet werden kann, unter Berücksichtigung

des Energiebedarfs des Gebäudes und der in den Warmwasserbatterien und -speichern gespeicherten Energiemenge.

3. Für jede aktive steuerbare Last, wird die verfügbare positive und negative Regelenergie durch Multiplizieren der Leistung mit der im Schritt 2. geschätzten Zeit t berechnet.
4. Die Summe der verfügbaren positiven und negativen Regelenergien wird auf Gebäude- und Energiesystemebene gebildet.
5. Das positive Regelenergiepotenzial (Flexibilitätspotenzial nach unten) des zu simulierenden Energiesystem wird in der Anzahl der Elektrofahrzeuge ausgedrückt, die zusätzlich aufgeladen werden können, ohne dass das Energiesystem ausgebaut werden muss; dabei wird angenommen, dass die Ladung jedes Elektrofahrzeugs 3,45 Stunden bei einer Ladeleistung von 2,9 kW dauert.

5.4 Ergebnisse an Fallbeispielen Biel-Benken und Malmö

Das simulierte Energiesystem bestehend aus einem hochskalierten 100-Häuser-Viertel in Biel-Benken wird nach Malmö repliziert. Die Abbildung 15 und Abbildung 16 zeigen, dass Malmö in Schweden, im Vergleich zu Biel-Benken in der Schweiz, im Winter 2017 eine geringere durchschnittliche Temperatur und Sonneneinstrahlung aufweist.

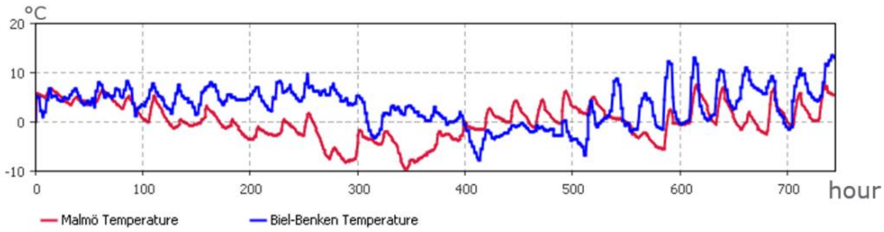


Abbildung 15: Temperaturvergleich zwischen Malmö und Biel-Benken im Januar 2017

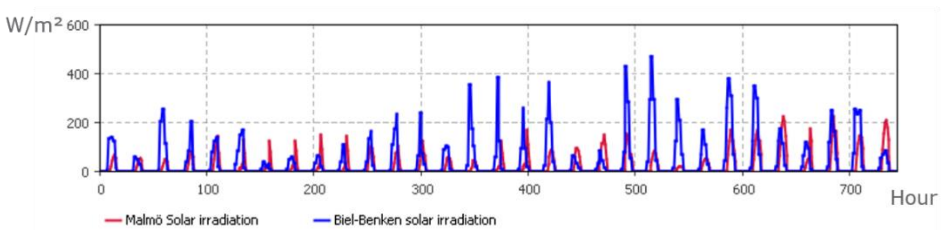


Abbildung 16: Vergleich der Sonneneinstrahlung zwischen Malmö und Biel-Benken im Januar 2017

Diese Unterschiede führen zu unterschiedlichen Simulationsergebnissen in Hinblick auf Wärmebedarf und Wärmeversorgung der beiden Fallbeispiele (siehe die Abbildung 17). Der Energiebedarf in Malmö (1070 MWh) liegt, über ein Jahr gesehen, um 140 MWh höher als in Biel-Benken (930 MWh). Daraus ergibt sich ein höherer Verbrauch von 45 MWh an Strom in Malmö als in Biel-Benken.

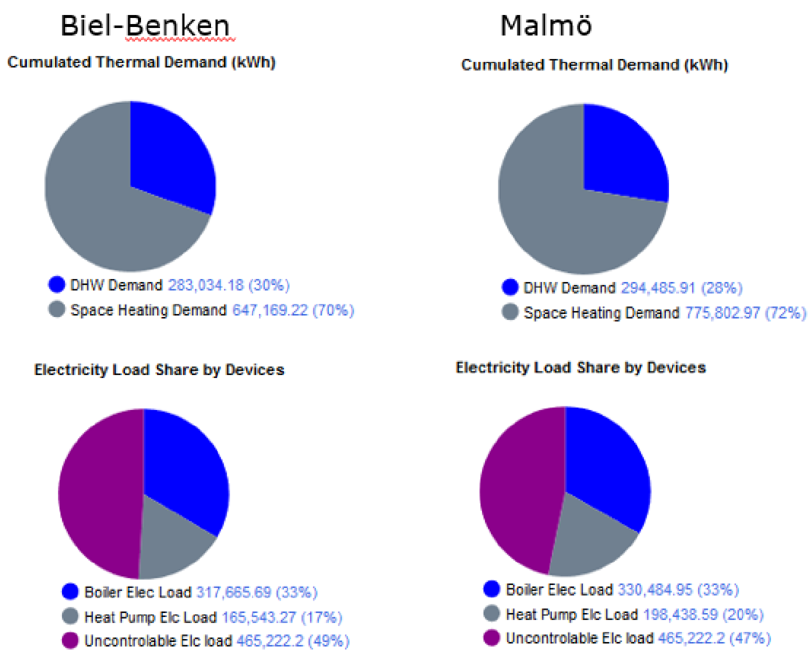


Abbildung 17: Simulierter Wärmebedarf und Strombedarf in Fallbeispielen Malmö und Biel-Benken

Im Vergleich zum Fallbeispiel von Biel-Benken, erzeugen die PV-Anlagen des Fallbeispiels Malmö 118 MWh weniger Strom, der zur Deckung von 48% des dortigen Strombedarfs verwendet wird. Wie in die Abbildung 18 ersichtlich, wird im Fallbeispiel Biel-Benken 56% des Strombedarfs durch PV-Strom gedeckt.

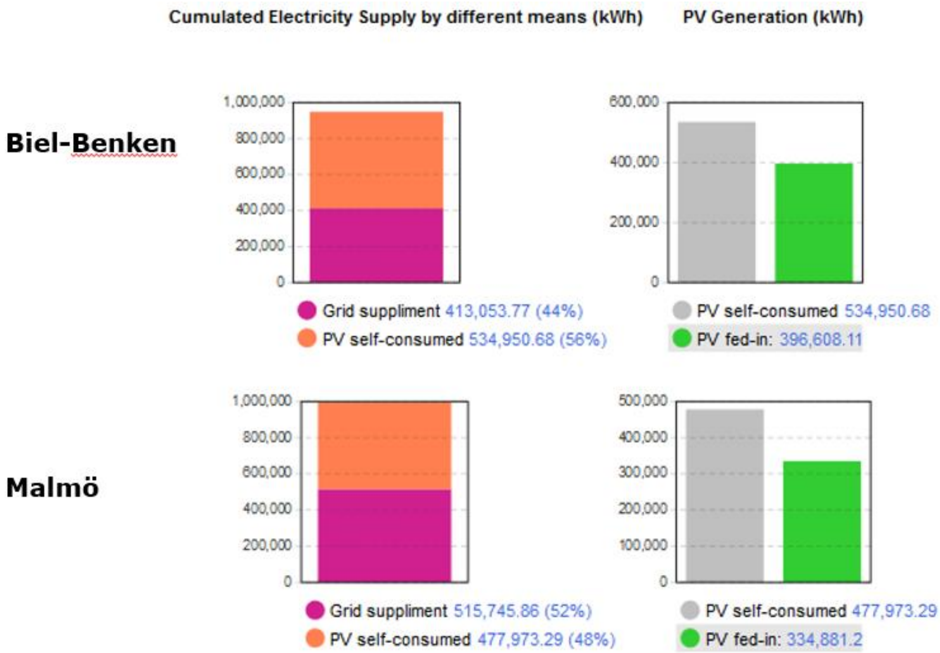


Abbildung 18: PV-Erzeugung und Einspeisung/Eigenverbrauch in Fallbeispielen Malmö und Biel-Benken

Die Ergebnisse der Simulation sind in der Tabelle 3 dargestellt. Man stellt fest, dass das Energiesystem im Fallbeispiel Biel-Benken ein höheres Flexibilitätspotenzial zur Reduzierung der elektrischen Last und ein geringeres Potenzial zur Erhöhung der Last aufweist als das Energiesystem des Fallbeispiels Malmö.

Tabelle 3: Durchschnittliches Flexibilitätspotenzial in Fallbeispielen Malmö und Biel-Benken

Standort	Durchschnittliches Flexibilitätspotenzial nach oben in kWh (negative Regelenergie)	Durchschnittliches Flexibilitätspotenzial nach unten in kWh (positive Regelenergie)
Biel-Benken	1128	540
Malmö	1176	514

Der Grund für ein höheres Flexibilitätspotenzial nach unten im Fallbeispiel Biel-Benken (540 kWh) lässt sich dadurch erklären, dass die Sonneneinstrahlung in Biel-Benken höher ist. Dies führt dazu, dass der durchschnittliche Ladezustand der Batterien paar Prozentsätze höher in Biel-Benken als Malmö liegt. Somit können die Batterien im Fallbeispiel Biel-Benken im Vergleich zum Fallbeispiel Malmö, im Falle eines Leistungsüberschusses im Netz, mehr Strom ins Netz zurückführen, um die Systemstabilität zu gewährleisten. Diese Flexibilität, die durch steuerbare Lasten und Batterien bereitgestellt ist, ermöglicht die gleichzeitige Ladung von 64 zusätzlichen EVs ohne Beeinträchtigung der Netzstabilität im Fallbeispiel Biel-Benken. Im Fallbeispiel Malmö können laut Simulationsergebnisse 60 zusätzliche EVs geladen werden.

6 Verbreitung der Projektergebnisse und Veröffentlichen von Forschungsergebnissen

6.1 Verbreitung der Projektergebnisse

Die folgende Tabelle stellt eine Liste der während der Projektlaufzeit durchgeführten Kommunikationsmaßnahmen dar.

Tabelle 4: Liste der Kommunikationsaktivitäten, die während des Projekts stattgefunden haben.

Jahr	Veranstalltung / Kommunikations-plattform	Beschreibung
2017	IST 2017 International Sustainability Transition conference, 18-21. Juni, Göteborg, Schweden	Organisation einer Dialogsitzung zum Thema „Von lokalen Experimenten bis hin zu groß angelegten Energiewandlungsprozessen“ mit Beteiligung von ReFlexPraxispartnern.
	Smart Energy Systems Week, 16-19. Mai, Österreich	Teilnahme an den Diskussionen der Smart Energy Systems Week in Österreich im Namen des ReFlex-Projekts
	ERA-Net SG+ annual event, 8-9. Juni in Bukarest, Rumänien	Feedback-Gespräch zum ReFlex Projekt, Teilnahme an ERA-Net SG+ Working Groups
	IEA Vernetzungstreffen, 12 Oktober, Salzburg	Gespräch über „Die Rolle von Smart-Grids in der Transition zu Nachhaltigen Energiesystemen“
2018	Smart Energy Systems Week, 16-19 Mai, Österreich	Teilnahme an Diskussionen der Smart Energy Systems Week in Österreich im Namen des Projekts ReFlex sowie eine Posterpräsentation zum Thema "Replizierung von Smart-Grid Solutions: Nicht kopieren - Mitgestalten!"
	International Sustainability Transitions Conference (IST 2018), 11-14 Juni, Manchester, Grossbritanien	Es wurde eine Dialogsitzung zum Thema "Regulatorische Innovationszonen als neue transformative Innovationspolitikinstrumente" organisiert und ein Artikel über "'Replizieren' von Smart-Grid-Erfahrungen: eine sozio-technische Analyse' wurde vorgestellt. https://app.oxfordabstracts.com/stages/329/programme-builder/submission/27618?backHref=/events/311/programme-builder/view/sort/author&view=published
	Smart-Grids Kongress 2018 – Smart Data for Smart-Grids, 3 Dezember, Fellbach, Deutschland	Präsentation über „Wie replizieren? - ´Reflex´ - ein EU ERA-Net Smart Energy Systems Projekt“ https://www.smartgrids-bw.net/fileadmin/images/demo/mobifyjs/SMART_GRIDS-KONGRESS.pdf
	Think Smartgrids, 3 Juli, Mulhouse, Frankreich	Präsentation über ReFlex und die Vorteile der transnationalen Zusammenarbeit während einer vom französischen Smart-Grid Verband "Think Smartgrids" organisierten Veranstaltung.

		http://tsa-mulhouse2018.insight-outside.fr/
2019	Webinar – ReFlex Abschlusskonferenz, 20 Febuar, Leonardo Energy	Wie kann man Lösungen zur Lösung der Flexibilitätsproblematik replizieren? Präsentation des ReFlex-Ratgebers https://www.leonardo-energy.org/resources/1550/how-to-replicate-solutions-for-the-flexibility-challenge-ref-5c45b2485ba86
2016-2019	Projekt Webseite	Artikel über die Demoprojekt Besuche und CoPs workshops, die im Rahmen vom ReFlex Projekt stattgefunden haben http://reflex-smartgrid.eu/index.php/news
2017-2019	LinkedIn	LinkedIn Gruppe zum Thema Smart-Grid Transition, die für die Verbreitung von Ergebnisse genutzt wurde, Leiter: Klaus Kubeczko, AIT (103 Mitglieder) https://www.linkedin.com/groups/7489503/profile
	Twitter	Regelmäßige Twitter-News über Projektaktivitäten und -ergebnisse

6.2 Veröffentlichung der Projektergebnisse

Das Modellierungsverfahren sowie die Methode zur Evaluierung der Replizierbarkeit und Skalierbarkeit von Smart-Grid Lösungen (siehe §5.1.2 und §5.1.3) wurden als Beitrag zu zwei Konferenzen eingereicht. Die Veröffentlichungen sind im Einzelnen:

1. Xiubei Ge[1], Enrique Kremers[1], Malcolm Yadack[2], Ursula Eicker[2]: Simulation-supported quantification of flexibility: assessing the potential for blocks of buildings to participate in demand response markets, 16th European Energy Market Conference (EEM 2019), Ljubljana, 18-20 Sep, 2019 https://www.eem19.eu/

2. Xiubei Ge[1], Enrique Kremers[1], Malcolm Yadack[2], Ursula Eicker[2]: Simulation-supported quantification of demand response actions applied in a block of residential buildings, 16th IAEE European Conference, Ljubljana, 25-28 August 2019, https://iaee2019ljubljana.oyco.eu/

[1] *Europäisches Institut für Energieforschung EDF-KIT EWIV, Emmy Noether Str. 11, 76131 Karlsruhe, Germany*
[2] *Hochschule für Technik Stuttgart, Schellingstr.24, 70174 Stuttgart, Germany*

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7.1 Bildquellen

Verwendete Fremd-Icons zur Veranschaulichung von *Abbildung 4*

- Strom: https://diybook.de/bauen-renovieren/elektroarbeiten/elektroinstallation/wichtiges-wissen-elektrischen-strom-haushalt, Abruf 06.06.2019
- Wärme: https://www.freeiconspng.com/images/heating-icon, Abruf 06.06.2019
- Auto: https://pixabay.com/images/id-3420270/ Abruf. 27.06.2019

8 Anhang – ReFlex Leitfaden

ReFlex Guidebook for the replication of use-cases tackling the flexibility challenge in smart energy systems

ReFlex Guidebook for the replication of use-cases tackling the flexibility challenge in smart energy systems

The ReFlex project
The ReFlex project aimed to develop a replicability guideline for the deployment of technologically feasible, market-based and user-friendly solutions for smart grids with a high level of flexibility. The focus was put on grids with an expectedly high level of renewable energy production which is effectively and efficiently used locally through mixes of measures from voltage regulation, demand response, energy management and storage.

ReFlex is based on evolving smart grid pilots in eight demo sites in Austria (AT), Germany (DE), Sweden (SE) and Switzerland (CH). Four of them – Salzburg-Köstendorf (AT), Island of Gotland (SE) and Malmö-Hyllie (SE), Lausanne-Rolle (CH) – involved demo sites situated in larger areas with a distribution system operator (DSO) as the main project partner. The other four of them – Biel-Benken (CH), Güssing (AT), Hartberg (AT) and Wüstenrot (DE) – are situated in smaller areas with less than 15,000 inhabitants involving private and public owned energy utilities, which did not have to unbundle grid operation from energy supply.
To extract as much practical knowledge for this ReFlex Guidebook, the project provided a balanced mix of partners, practitioners and experts from larger and smaller energy companies and municipalities as well as regulatory and other socio-technical context factors in different countries.

Drawing on the learning experience among ReFlex partners, replicability-guidelines were elaborated, to support the demo regions and the broader group of European smart grid stakeholders in deploying and advancing their smart grid initiatives and replication projects.

01.04.2016 – 31.03.2019

Acknowledgements
The Reflex-team of authors is indebted and thankful to the many active participants in the workshops and demo site visits of the ReFlex Community of Practice (CoP) during 2016-2018. Those practitioners, experts, municipal representatives and researchers have provided in-depth knowledge on successes and failures through their open and intensive discussions, thus providing the basis for this Guidebook. Without their contributions and the hospitality of the hosting organisation, this publication would not have been possible.

The project team is also thankful to ERA-Net Smart Grid Plus and the national funders from Austria, Germany, Sweden and Switzerland and the European Union’s Horizon 2020 research and innovation programme of this trans-national research project. Without the possibility to coordinate a meta-study and a Community of Practice across four countries, many insights and tools would not have been possible to make available through this publication.

1 Use Case #1 in Flexible Smart Grids: Short term voltage-stabilization in local electricity grid

2 Use Case #2 in Flexible Smart grids: Energy Management for business parks

3 Use Case #3 in Flexible Smart Grids: District Heating load management

4 Use Case #4 in Flexible Smart Grids: Shared use of local low temperature resources

5 ReFlex Toolbox

6 Final Recommendations

7 Annex
Technologies review

Smart Grids and distributed energy systems have been identified as crucial elements of the energy transition. Many innovative solutions have been developed to deal with the flexibility challenge going along with the integration of renewable energy into local energy grids. Engineers widely agree that technologies are at hand and many use cases are technically feasible, which has been demonstrated in many research and demonstration projects across Europe under optimised framework conditions. Now the question is:

How can technically feasible, innovative use cases, tackling the flexibility challenge, be replicated and deployed in other locations and contexts?

This ***ReFlex-Guidebook*** shall help those interested in implementing innovative solutions for flexible smart energy systems and smart electricity and thermal energy grids smart grids, which are technologically feasible, economically viable and user-friendly.

The guidebook shall help private and public actors and stakeholders, such as

- municipalities,
- local grid operators (e.g. distribution system operators and municipal energy utilities) and
- energy suppliers

in their endeavour to replicate or transfer smart solutions to their local contexts.

As any practitioner can tell, merely copying solutions, which have been promoted through conferences and site visits, does not work. Therefore, this guidebook will provide knowledge about the context factors to be considered when ***replicating*** innovative solutions ***in other locations***, particularly when transferring them to ***other countries***.

The recent developments in European Electricity Directive and Regulation aim at more active involvement of citizens in the energy system. It mainly allows for "citizens energy communities" and other measures to ***involve citizens***, "***active consumers***" and ***end-users*** in shaping the future energy system. Hence, replicating the use cases, described in this ReFlex guidebook, might become easier, which makes it timely to ***learn from the experiences of practitioners in eight demo-sites in Austria, Germany, Sweden and Switzerland*** made available through this publication.

Overview of Content

The ***first part*** of the guidebook will ***outline four typical Use Cases***, based on examples from the eight demo-sites in the ReFlex project. It includes aims, technical functionalities, assumed business and mission models, stakeholder-network constellations as well as the geographical context, the legal and regulatory context, the economic context and other social context factors to be considered for replication and adoption. ***Target groups***, both already established and new actors in the energy system, as well as municipalities, ***can focus on the use-case they are interested in***.
The use cases are addressing the ***flexibility challenges*** which either primarily deal with (a) availability and quality of ***power at any instant of time*** or (b) providing ***flexibility in balancing renewable energy production and use*** over a specific period-of-time. Two of the use cases are related to grid management involving ***grid operators and "active consumers" (B2C); the other two are related to business to business (B2B) energy services***.

The ***second part*** provides a ***checklist and toolbox*** for guidance in how to plan, develop and implement use-cases in replication projects. The ***target groups*** will be provided with general information as well as with specific tools relevant for local grid operators, as well as for municipalities.
Tools are related to learning processes, development of (cooperative) business models and mission model, technological replicability and upscaling, planning and decision making, end-user and stakeholder involvement, governance of transition process.
The second part includes information on Community of Practice, ReFlex Simulation model and other planning tools, Collaborative Business Models, Mission Models, citizen engagement and regulatory sandboxes.

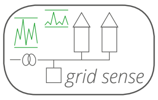
The motto of the Guidebook: Don't Copy – Co-create

After visiting Güssing – one of our demo-sites – Arnold Schwarzenegger proclaimed that "The whole world shall become like Güssing" ["Die ganze Welt soll Güssing werden"] as he was impressed by the many activities carried out in the frame of Güssing' renewable-energy-based local energy system. Transferring the many interesting solutions to other locations, i.e. replicating them in other contexts, does not mean copying or duplicating a blueprint.

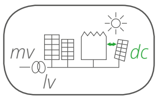
As experienced in the many discussions and interactions in workshops and sites visits throughout the ReFlex Community of Practice, intense cooperation and collaboration is required in the innovation process, as we are dealing with complex challenges and highly integrated solutions.
Thus, *Co-creation is the way forward* to replicate the *four ReFlex Use-Cases* in this book.

The four ReFlex Use-Cases

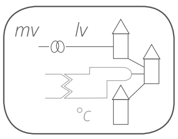
The following use cases are presented in part 1 based on experiences from eight demo-sites:



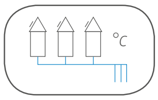
#1. *Short term voltage-stabilisation in local electricity grid:* this is based on empirical evidence from Biel-Benken (CH) focusing on load shifting and load management at the household level and from Salzburg-Köstendorf (AT) dealing with short term local low voltage grid stabilisation. Furthermore, the demo sites of Island of Gotland (SE) and Lausanne-Rolle (CH) provided valuable evidence
(Target groups: local grid operators, local grid owners)



#2. *Energy Management for business parks:* this is based on empirical evidence from Hartberg (AT) focusing on optimised use of locally generated renewable energy in a business park
(Target group: business park owners and operators, local grid operators)



#3. *District heating load management:* this is based on the implementation of a smart district heating system in Malmö-Hyllie (SE) to use the building stock for load management purposes, as well as examples from Güssing (AT)
(Target groups: municipalities, district heating system operators – public or private utilities, property owners / facility managers)



#4. *Shared use of local low-temperature resources:* this is based on empirical evidence from Wüstenrot (DE), a community-owned low-temperature agrothermal collector combined with heat pumps supplying heat to of a newly built neighbourhood
(Target groups: municipalities, house owners / facility manager)

What we understand by Flexibility – challenge, services, aims, purpose

The *flexibility challenge* as understood in this Guidebook goes along with the integration of distributed renewable energy sources into local energy grids. Most discussions on flexibility are focussing on the issue of grid stabilisation for which local grid operators are searching for economically feasible solutions. Other actors in the energy system are also facing flexibility challenges of some sort or can provide flexibility services to grid operators or other actors in the energy system.

Those smart solutions, we are looking at, focus on providing flexibility of two different *purposes and aims*:

(a) *Flexibility for Power* enables to *match generation and loads on time*, across seconds and minutes in the power-grid. These energy system services aim to maintain
(i) quality of power,
(ii) local grid stability as well as
(iii) availability of power supply for congestion management and operating reserve under changing conditions due to increasingly volatile energy generation.
(b) *Flexibility in Energy-logistics / Flexibility for Energy* enables the overall balancing of the energy system (including the electricity and heat system) by energy generation and use across a period: minutes, hours, days and seasons. The aim of these energy system services is to manage variability and uncertainty in the energy systems, to
(i) manage the just-in-time feed-in and withdrawal of energy, to
(ii) make locally produced renewable (access) energy available for optimal local energy-use and to
(iii) optimize decarbonization of the energy system across weeks up to months.

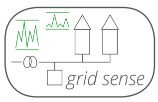
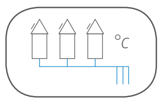
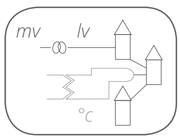
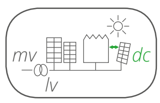
Analysing the four ReFlex Use-Cases, we have identified solutions for the following ***flexibility services***:

- ***end-user's services*** such as incentivised active demand response via heat pumps, through temperature control of heated rooms,
- ***generation/supply side services*** such as shifting of heat production for electricity grid stability purposes in CHPs, control of PV production that is either fed into the grid or stored in a battery depending on grid conditions (voltage and frequency) ***infrastructure modifications*** to improve flexibility capacity and grid stability such as variable transformers for neighbourhoods, low-temperature earth collectors for neighbourhoods and direct DC lines from PV to large scale heating units.

- ***direct energy storage*** such as thermal storage in building mass and electricity storage through second-life batteries for short term frequency reserve.

The ReFlex Use-Cases, as many other flexibility solutions cannot, and need not, be aiming at one or the other flexibility service. All our use cases can be supportive for grid stability, but not all focus on optimising local energy use.

Table 1: Main Flexibility Services provided by use-cases

	Flexibility for Power	**Flexibility in Energy-Logistics**
Grid Management B2C with actively engaged energy end-user	Short-term voltage-stabilization in local electricity grid 	Shared use of local low temperature resources 
Load & Energy Management Services B2B without active engagement energy end-user	Load shifting for load-management of energy-utilities 	Energy Management for business parks 

What we understand by Replication

In this guidebook, the focus is on the replication and transfer of smart grid solutions to new locations and contexts. Replications of smart grid solutions are targeted, problem-solving attempts of learning from one experiment or innovation project and transferring the (successful) elements of this demonstration project to another site.

Our concept of replication is broad and comprises the different distinctions made in the current literature regarding the deployment of feasible socio-technical solutions. Often a main distinction is made between

(A) different forms of transfer of functionalities (accumulation) or scaling-up ***within given socio-technical contexts*** and
(B) more far-reaching transfer of functionalities and/or up-scaling strategies ***in other socio-technical contexts.***

Transfer of functionalities in the former case is considered here as ***replication in the narrow sense of this guidebook*** or, when different forms of system transformation and institutional change are involved, upscaled replication or transformation.

Deployment in the same context (A) includes different accumulation and scaling-strategies such as the roll-out of new products and services, or the expansion of pilot projects. Deployment in different contexts (B) includes different transfer and scaling strategies such as the replication of smart grid solutions in new contexts and locations or shaping of institutional and rule sets. A fundamental tenet in the current literature (e.g. Sigrist et al. (2016),[1] Naber et al. (2017),[2]), which has been empirically confirmed and specified in the ReFlex project is the importance of socio-technical context dimensions such as socio-cultural, institutional, political, spatial and economic contexts as pre-conditions, incentive and shaping factor of deployment processes.
Moreover, the replication and up-scaling of solutions from pilot projects needs to be integrated into a broader perspective of systemic change to live up to the longer-term aim of transforming the existing electricity grid, also beyond the replication and economic success of specific smart grid pilot solutions. An attempt to define separate mechanisms at play in such a transition towards a more sustainable energy system is e.g. undertaken in the following table.

Table 2: Deployment strategies for socio-technical solutions

Concerning smart grid pilot projects it is crucial to ask: Which elements and solutions of the pilot project can be replicated somewhere else? Which context dimensions are critical for the replicability of these solutions? If these critical context conditions are not matched at the new place where a smart grid solution should be implemented, the solution in question is either not applicable, or in some cases, framework conditions might need to be changed to accommodate the smart grid.

Against this background, we suggest an analytical framework for replication which is sensitive to the specific institutional, economic, technological, geographical and stakeholder contexts of the smart grid pilot projects on the one hand and the different contexts at those places where outcomes of the experiments are supposed to be taken over on the other side.

The first question to be asked is: ***Which elements of the smart grid pilot project are expected to be transferred to another location?*** In principle, the range stretches from highly standardised technical products (e.g. a new monitoring or visualisation device) to the whole set-up and system configuration of a pilot project, which can be implemented in a similar way somewhere else.

		Deployment Strategies	
		Transfer	(Up-)scaling
Socio-technical context: spatial, socio-cultural, institutional, political and economic	Same context	**Accumulation** roll-out and diffusion of new products and services	**Growth** expansion of pilot projects
	Other context	**Replication** replication of smart grid solutions in new socio-technical contexts	**Upscaled replication** standardisation of technological components, otherwise context-independent, and **Transformative replication** shaping institutional change

Analytical framework

Replication rarely means implementing an identical smart grid project or solution at a different place. Instead, individual elements or innovations developed within a smart grid pilot project are transferred to new contexts. This transfer often requires some level of translation or adaptation of these solutions.

While the first case mainly requires some technical preconditions to ensure the operability of a technical device in a new context, the much more complex set-up and system configuration are transferrable only under particular circumstances.

[1] Sigrist, L.; May, K.; Morch, A.; Verboven, P.; Vingerhoets, P.; Rouco, L. (2016): On Scalability and Replicability of Smart Grid Projects—A Case Study. Energies 9 (2016), 195. https://www.mdpi.com/1996-1073/9/3/195

[2] Naber, R., Raven, R., Kouw, M., Dassen, T. (2017): Scaling up sustainable energy innovations. Energy Policy, 110 (2017) 342–354

We suggest '***use cases***' to describe the socio-technical transfer of smart grid solutions at an intermediate and sufficiently concrete level.[3] Such use cases comprise the detailed descriptions of functionalities and actions related to specific solutions (e.g. the type of actors involved, their behaviour and action[4]). For replication to other locations, it is also necessary that the analysis of use cases also comprises different context conditions such as business models, regulatory situation and more.

Therefore, in our replicability approach, when analysing a use case as socio-technical configuration we take the dimensions into account, which are outlined in the following table.

Table 3: Socio-technical Components & Context Factors

	ReFlex Use-case components	Socio-technical context factors of use-case
Technical functionality and technology	• Functionalities in energy system • Key technological components and configurations, as well as digitalisation, ICT and artificial intelligence applications	• Relevant system boundaries • Energy grid configuration • Interoperability • Availability of know-how
Context dimensions		
Space and Geography	• Physical Infrastructure • Potential for local energy generation	• Size of replication site, • Climate conditions
Institutions and Regulatory	• Organisations and actors groups involved	• EU and national legislation on competition and energy market regulation • Energy market institutions • Standardisation
Social and political practices, networks and culture	• Mission model (beyond economic benefits) • Actor and stakeholder constellation	• Cultural Norms, • Social practices of end-users • Citizens' acceptance and trust in institutions
Economic	• Business Model of private and public actors • Collaborative business model	• Culture of cooperation and costs of coordination • Macro-economic benefits

[3] This approach build on existing methodologies to describe use cases as part of IT systems for software developers and system architects (see ISO/IEC 19505-2: 2012) and further adapted to the design of smart grid systems (Gottschalk et al., 2017).

[4] Gottschalk, M., Uslar, M., Delfs, Ch. (2017):
The Use Case and Smart Grid Architecture Model Approach: The IEC 62559-2 Use Case Template and the SGAM applied in various domains. Springer Briefs in Energy Springer.

1 Use Case #1 in Flexible Smart Grids: Short term voltage-stabilization in local electricity grid

The use case describes how an operator of a local electricity grid (often a distribution system operator (DSO) or municipal energy utility) could mitigate local grid instabilities at low voltage level caused by decentralised generation. Power injection into the low voltage grid endpoints, typically by photovoltaic systems, has the potential to raise the local voltage significantly, thus causing power quality issues (e.g. harmonic distortions). In this use case, the local electricity grid operator leverages the flexibility potential offered by loads with shifting characteristics (heat pumps, electrical heaters, electric car (EV) chargers) and storage units (thermal and electric storage).

Keywords
local grid operation, DSO, load shifting, storage, flexibility, demand side management, low voltage grid

Reference – Demo Site Biel-Benken

The overall goal of the Biel-Benken demo site was to demonstrate the technical feasibility of a fully decentralised residential demand side management system. The Swiss University of Applied Science and Arts of Southern Switzerland (SUPSI) developed a decision algorithm which uses the local voltage levels to estimate the power at the transformer. The voltage profile is used in combination with the tariff profile to drive a multi-objective optimisation system. After the completion of the research project, the technology is now further developed in an industrialisation project, under the name GridSense, in cooperation with Alpiq, a leading Swiss electricity and energy services provider. The industrial prototype is installed at the Biel-Benken demo-site.

Image 1
Demo-site Biel-Benken
(Source: ReFlex website)

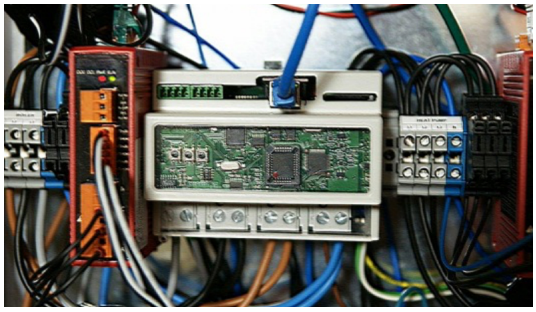


Image 2
Prototype of energy controller in Biel-Benken
(Source: ReFlex website)

Use case outline
The Flexibility Challenge

Scope and objectives of the use case
This use case may be applied to areas with a high penetration of decentralised generation in the low voltage grid. The higher the penetration, the higher the effect on low-voltage stability, thus increasing the need for mitigation actions. The objective of this use case is to utilise the existing flexibility potential to mitigate grid instabilities and to allow a more significant share of generation from local renewable energy sources.

Narrative of the use case
In Europe, solar generation is reaching significant levels of penetration, which is expected to rise further thanks to a wide range of environmental, social, technical and economic drivers. From this growth, a range of issues related to the operation and economic impacts of photovoltaic (PV) generation on the power grid arises. From a technical point of view, the stochastic nature of solar production causes operational challenges. Among them, the unbalance between production and consumption, overvoltage and overload of grid components are the most common ones.

The increase in self-generation tends to reduce the income from grid-fee for local grid operators, considering that the grid component of the electricity tariff is usually a function of the consumed energy. On the other hand, due to the above-mentioned technical challenges, the investments in the network infrastructure are expected to increase.

Among the technical measures for mastering this challenge, the intelligent management of the flexibility available at the demand side is recognised as a promising approach to relieving the network stress. In Europe, most of the grid issues related to PV penetration are located in the low voltage levels of distribution grids, close to the demand side. To avoid creating unbalances in the distribution grid and to improve the grid energy efficiency, demand side management, alongside with local storage, could be used to realign consumption and production.

What can be replicated? How could this be achieved?

What to do as Municipality?
- Clarify regulatory aspects
- Clarify the necessity for voltage control
- Clarify the value of these voltage control mechanisms

What to do as actor in the Energy Sector?
- Clarify regulatory aspects
- Develop innovative business models

What can be replicated from Demo Site Biel-Benken? (GridSense)

The Biel-Benken demonstration project has already been replicated and upscaled in SoloGrid, a joint flagship project of Alpiq, AEK, Adaptricity and Landis+Gyr in the municipality of Riedholz in the Swiss canton of Solothurn. The goal of the project, which was supported by the Swiss Federal Office of Energy (SFOE) and received funding from the canton of Solothurn, was similar to Biel-Benken project: to analyse the energy flow within an electricity distribution grid and to optimise it using artificial intelligence, in order to minimise the need for grid development measures. In SoloGrid Alpiq trialled a fully industrialised control unit, ready for mass production.

Context conditions

Assumptions

The low voltage grid has voltage magnitude variations that justify the need for grid management intervention (actions by the grid operator). Use case conditions are also met when forecasted penetration of distributed electricity generation and loads justifies a preventive action to avoid voltage magnitude variations.

Geographic and Environmental Conditions

As this use case is based on an existing grid structure, climatic conditions are less relevant. However, in rural areas with long distances between grid-connected buildings, the electricity grid might be weaker than in urban areas. The weaker the grid, the more distributed energy resources (DER) and loads may lead to voltage magnitude variations. Therefore, this use case may be applied in rural areas and in regions where power grids experience congestion issues due to the high penetration of renewable energy sources.

Prerequisites

A new regulatory framework needs to be defined that specifies how the provision of flexibility is remunerated and allows to set up innovative electricity and network tariff schemes. Grid users must accept to install a remotely controllable or independently controlling system behind the meter. Incentives or marked based mechanisms for the grid users to provide flexibility to the local grid operator needs to be deployed. In the case of grid users with a local energy generation, such as photovoltaics (PV), the flexibility mechanisms should not conflict with the optimisation of the self-consumption rate.

Legal and Ethical Considerations

All relevant legal guidelines of the country must be considered, as well as all contracts between local grid operators and the grid users must be legally completed, for this, a lawyer for contract law must examine the documents and confirm the legal correctness of the contracts to avoid any further complications.

Key Performance Indicators (KPI)

In this use case, several KPIs are used to represent the low voltage grid and the performance of a voltage stabilisation system, such as ***Voltage Magnitude Variations*** and ***Voltage Stabilization Performance***. The primary criterion for short term voltage stabilisation is to comply with the allowed voltage band.

Context conditions – Demo Site Biel-Benken

The pilot project PowerGrid has been set up explicitly to test the GridSense solution in the field and to allow developing it further. In the EBM operated grid of Biel-Benken, Switzerland, a low voltage (LV) feeder with a high PV penetration that leads to considerably high voltage fluctuation was selected. In spring 2015, four houses equipped with rooftop PV plants and heat pumps were equipped with control and monitoring system. Additionally, EBM also provided monitoring of the low voltage end of the transformer. The pilot system became fully operative in the summer of 2015. Since then, several versions of the developed hardware and software have been tested using this testing platform. The installation and commissioning of photovoltaic, house battery, charging station for electric vehicles, electric boilers and heat pump as well as the validation and calibration of the physical models of these GridSense components were successfully tested in the PowerGrid pilot project. The PowerGrid pilot system proved itself very useful for the development and the testing of Demand Side Management (DSM) solutions.

Local energy system and stakeholders

Local grid infrastructure
No further components.

Generation and storage
No additional components are required for this use case. Pre-existing generation, loads and storage components flexibility can be utilised. However, the more generation, load and storage components are installed, the higher the optimisation potential for demand side management. Tariffs designing incentivising local flexibility could also lead to the installation of additional generation and storage components at grid users' premises.

End-user components "behind the meter"
A load monitoring and control equipment is installed in the grid users' premises, behind the meter. The equipment will monitor and control local loads and storage systems, by sending control commands with priority order. Depending on the deployed local control algorithm, a central intelligence may also be needed. If many grid users along one power line use the control equipment, they could optionally interact with each other improve the flexibility performance.

Actor-groups and Stakeholders-groups (third parties, ownership)
The key partners to operate a low-voltage stabilisation system are:
- operator of the local electricity grid (DSO or municipal electricity utility)
- service provider/manufactures
- grid users (e.g. businesses, house owners, private households)

Key partners – Demo Site Biel-Benken

The key partners in the Demo Site Biel-Benken are the local electricity utility (EBM AG), the service provider and manufacturer of the system (Alpiq InTec AG) and the grid users (single-family households). The GridSense system developed by Alpiq is a business-2-business product offered to EBM. EBM then provide the product to the end-users, negotiating with them. In this specific project demonstrator, the hardware was provided on a free basis to the customer by the electric utility and the manufacturer. The goal was to demonstrate the technical feasibility of a decentralised load management solution.

Mission model
What are the needs? How is value created?

Economic, social and environmental needs
The reductions of voltage instabilities enable higher penetration of distributed local renewable generation, increasing the community autarky and self-consumption and reducing the carbon footprint.

Beneficiaries / Stakeholder
- Local Grid Operator
- Grid users
- Service provider/manufacturer
- Energy supplier: not involved in this use case

Value Propositions
- Local Grid Operator: increased voltage stability, cost saving due to the reduction of infrastructure improvements needs
- Grid users: cost saving thanks to innovative tariffs schemes and the increase of own self-consumption (for end-user with PV generation)
- Service provider/manufacturer: profit from sold devices and licenses.

Collaborative / Cooperative Business Model(s) along the value chain ***Local Grid Operator:*** operate the low voltage grid efficiently, avoid unnecessary grid investment
Manufacturer: production of new control devices covering new business cases
Grid users: active role in the low voltage grid

Biel-Benken

The use case allow a higher penetration of local renewable energy generation in the low voltage grid. The solution is a step toward a decarbonised society. Moreover, the usage of local green energy empowers the community members.

Collaborative Business Model – Demo Site Biel-Benken

As the control equipment stabilises the local power grid and prevents grid issues through load shifting, a reduction of the network charge is achieved that benefits to all customers of EBM; thus, not only the involved households equipped with control boxes but also people located in the test area take advantage of this investment. The local grid users also profit from cost-saving thanks to increased self-consumption and attractive tariffs. Data collected that give detailed information about the status of the power grid is of value for the local grid operator and/ or a local service provider. This information allows to develop further innovative solutions for grid stabilisation tailored to users' needs.

Framework conditions for adoption and replication

Market regulations
The main actor for adoption and replication is the local grid operator. The role of the local grid operator is strongly regulated, and therefore innovation regarding regulation is crucial. In Switzerland, for instance, the new 2018 Energy Law allows the local grid operator to install load management control boxes behind the meter and offer alternative power-based tariff schemes to customers to provide incentives to reduce peak loads. This new legal framework increases the likelihood of replication and adoption significantly.

Financing
Financing aspects are not critical for this use case per se. They are dependent however on favourable market regulation. The hardware itself is in general not cost intensive. However, installation costs must not be underestimated. In particular, individual electrical installations at the grid users' properties might become too high.

Social acceptance
In order to have a high social acceptance, there is a need for a voltage stabilisation system, which is fully automated and does not have any impact on end-user comfort. This condition is guaranteed by the fact that no equipment or services involve action by or continuous permission from the grid-users. The risk is also reduced by the fact that previously affected appliances in households such as dishwashers and laundry machines are so efficient today that they are not considered for demand response measures.

Identified barriers to replication and scalability

Technology Level
No technology breakthrough is necessary to implement this use case. However, there are high barriers: the control of household devices is not standardised, and it is still very fragmented. These barriers slow down the replicability and upscaling. Another constraint is about components cost. The control unit manufacturers market is highly competitive with low margin on hardware costs. Manufacturers are very cautious about adding additional technology to their product line. The lack of a standard for the control interface/management of demand control solutions is one of the leading technological obstacles to the uptake of demand response technologies.

Market level
The major challenge is coming from regulation. It can be very tough for the local grid operator to justify an investment in behind-the-meter control boxes because the national authority does not support this type of investment since it's not the most efficient and cost-effective solutions compared to other existing technologies. Another challenge is to develop innovative tariff schemes that benefit to the grid operator and the grid users. Deployment of a new type of tariffs scheme, for instance, power-based tariffs, can be blocked by existing market regulation.

Stakeholder Adoption level
A potential barrier is a lack of public acceptance from end-users. The cost saving for the grid users may not be significant enough to offset the costs of installing the additional control box and so achieve economic profitability.

Technology Level – Demo Site Biel-Benken

GridSense is a Demande Side Management solution of the Alpiq InTec Group, which has been developed at SUPSI, the University of Southern Switzerland. It allows for autonomous decentralised control of dispatchable loads such as boilers, charging stations for electric vehicles (EV), battery to grid systems (B2G) and heat pumps. The GridSense solution enables new emerging energy services such as energy monitoring and automatic demand side management for distribution grid operators and power companies, as well as optimised self-consumption services for end users. The sensing and actuation parts are performed through the GridSense unit, a smart meter running with intelligent algorithms in a decentralized way.

The developed algorithms can operate in different optimisation modes:
- Grid support: Based on local voltage measurements, the algorithm shifts the power consumption from periods in which the voltage is low to periods in which the voltage is high.
- Cost reduction: Based on energy tariffs, the algorithm shifts power consumption to periods in which the electricity cost is low.
- Self-consumption: By monitoring the electricity flow and the house load and the production of the PV plant, the algorithm optimises the self-consumption of the end user, and therefore its energy costs.

2 Use Case #2 in Flexible Smart Grids: Energy Management for Business Parks

The use case deals with an optimized energy management of a business park or similar site with multiple purpose buildings and other infrastructures such as parking space, event halls etc, including renewable energy power and heat generation. Energy can be distributed through a local heating network, the low-voltage electricity grid and direct DC connection between PV and local end-users. The business park can be manged in an optimised way based on the availability of on-site renewable energy production, energy storage capacities, and the local consumption with a broad range of end-use services. In addition, there is sector coupling by E mobility charging stations and peer-to-peer solution (direct line) for the surplus of power generated by renewables within the business park.

Keywords
Building Energy Management, Load Shifting, local flexibility, optimisation

Abstract – Demo Site Hartberg

The demo site in Hartberg is a business park labeled as "Ökopark Hartberg" with office buildings, a cinema and museum. It is situated in Styria, a state of Austria, which has significant forest resources. Stadtwerke Hartberg and its different affiliated organizations are 100% owned by the City of Hartberg. The Stadtwerke operates the grid and acts as the local (almost monopolistic) provider of electric energy. One of the particularities of the demo site is that the business park itself is run by the Stadtwerke which allows them to maintain close relationships with end-users such as companies renting offices, operators of the aquarium, cinema and museum in the leisure complex, owners of electric cars who regularly charge their cars.

Image 1
Electric storage (left) and power inverter (Source: ReFlex website)

Image 2
Solar carport at ÖKOpark Hartberg for local power generation and EV charging (Source: ReFlex website)

Use case outline
The Flexibility Challenge

Scope and objectives of the use case
The use case can be applied to business parks or similar sites with multiple purpose buildings and other infrastructures such as parking space, event halls etc, including renewable energy power and heat generation. The objective is to optimize energy consumption, storage and consumption to reach the goal of low-, zero- or even positive energy business-parks on the one side and on the other side to provide flexibility of power and energy-logistics to energy infrastructure operators and energy suppliers. The scaling of such a use-case is limited to the maximum size of a business park or similar site with the potential to optimize energy flows as if being a single user to the electricity grid and other energy infrastructures outside the premises

Narrative of the use case
The climate and energy policy of European countries aims at significantly reducing CO2 emissions by 2030 in all areas including industry and businesses. Hence, National Energy and Climate Plans will likely include also measures for increasing energy efficiency, incentivising on-site production of renewable energy and reducing fossil-fuel-based energy consumption of industry and businesses in heating, cooling of buildings, transport etc. Future-proof business-parks should therefore develop business models for energy management and energy services, which allow their customers to contribute to those societal goals and at the same time save in energy bills.

What can be replicated? How could this be achieved?

What to do as Municipality?
- Actively develop a mission model together with the actors and stakeholders of the business park including environmental and regional development vision and medium- and long-term goals
- Actively communicate with stakeholders and actors, such as owners and managers of business parks and interested businesses to present the use case and its benefits, sharing the vision and medium- and long-term goals developed in the mission model

What to do as actor in the Energy Sector?
- Clarify regulatory aspects together with the national energy regulator and, if needed, apply for the creation of a regulation innovation zone (regulatory sandbox), which allows to explore and test various technological solutions and business models.
- Enter into collaboration with local companies (e.g as flexibility service provider with demand response) and other actors in the energy system (e.g. local grid operator, distributed energy producers …) to develop cost-efficient and flexible solutions that will support the use case implementation.

Context conditions

Assumptions

The use case assumes that industrial and commercial companies increasingly want to cluster at sites with favourable conditions for optimizing their energy consumption towards local generation and consumption as well as reducing their CO2 emissions. If the energy management should provide flexibility services, the renters (tenants) need to be willing to participate in the concept even if small disadvantages occur compared to other alternative options, as long as they are compensated by other services or savings.

Prerequisites / Framework Conditions

A prerequisite for the replication of the use-case in our demo-site is the existence of a business case for providing energy services to the enterprises renting the office space and other infrastructures. Furthermore, unlike in the case of a fully integrated municipal energy utility, in cases of an unbundled actor constellation a collaborative business case would be needed that is favourable for the owners of the on-site energy infrastructure, the energy infrastructure operator as well as the energy suppliers.

In case of ownership of the local energy generation and grid operation being separated, e.g. the local PV is owned by the business park and grid operation is manged by a local grid operator (DSO), the latter would either have to tolerate a direct line for peer-to-peer exchange of electricity within the business park, or allow for the use of its grid. Otherwise peer-to-peer exchange might not be profitable.

Geographic and Environmental Conditions

The use case will find favourable conditions in regions with availability of local renewable energy sources (e.g. biomass), space for PV as well as space for storage of access energy. Thus, geographic conditions like nearby forests or favourable geothermal conditions are favourable. Furthermore, large business parks with favourable topographic conditions and space for PV on buildings increase the profitability of such use case.

Legal and Ethical Considerations

European directives, national laws and Energy market regulation must provide the room which allows or facilitates contractual arrangements between business park owners/operators, local energy infrastructure operators and tenants. In the case of direct DC connections attention need to be drawn on grid codes, which might be hindering its implementation.

Key Performance Indicators (KPI)

In this use case, KPIs are mainly related to the optimised energy-logistics, e.g. use of locally generated renewable energy, the degree of net autonomy (percentage of kWh of heat and electricity consumed from external sources) With respect to serving the flexibility demand of local grid operators indicators could include kW*minutes of demand response and kW*minutes of electricity from storage provided. The reduction of fossil fuel consumption in kWh is another KPI for reducing CO2 emissions, in cases where this is part of the mission model benefits.

Example: Framework conditions – Demo Site Hartberg

The business park, Ökopark Hartberg is a local micro-grid due to its neighbourhood with a biomass-based CHP on the business park's premises. The energy infrastructure includes the biomass based CHP, low-energy buildings, PV for E-mobility charging and a direct power line from the PV plant to the aquarium. Thermal heat comes from the CHP and additionally required electricity is made available through the local grid of the Stadtwerke Hartberg.
The management board of Stadtwerke Hartberg had a strong leadership role and assumed responsibility over several years, particularly linking municipal policy making with the local business sector and the various actors at the business park. This role as care-taker to coordinate the complex network of stakeholders and actor groups of the business park from medium to long term was identified as one of the key success factors in this case.
Another aspect which needs to be considered in replication is that, on the demo site, the business park is also run by the municipal utilities. Thus, not only do they have to have a close relationship with end-users as grid operators and customers in an energy supply contract (electricity, heat and electric cars charging) but also as landlord to tenant (firms renting the offices, operating of the entertainment complex (cinema/museum), renting space in a car park). Hence, the basic assumption is that there is an atmosphere of cooperation among the different actors and stakeholders.

Local energy system and stakeholders

Local grid infrastructure
The mix of local energy infrastructure consists of local heating network, low-voltage electricity grid, and direct DC-connections. It can be replicated in any business park, assuming collaboration between key actors. The limits to upscaling can be extended to the medium-voltage level if the size of business park requires more than one substation and local heating grid could be linked up with a larger district heating grid. However, the consequences for a profitable collaborative business case need to be considered.

Generation and storage
The use case could include serval renewable energy sources to generate power and or heat. In addition, sector coupling is possible. Therefore, PV and wind plants, biomass combined heat and power plants (CHPs), thermal and electrical storages and heat pumps as well as charging station for electric vehicle could be integrated into this use case. Thus E-charging, thermal storage and batteries can also be part of local energy-logistics, thus increasing the potential for flexibility services.

End-user components "behind the meter"
End-users can also be integrated into this use case. It is crucial to check that the device standards are compatible with the overall energy management platform.

Actor-groups and Stakeholders-groups (third parties, ownership)
Operator of the system can be either the municipality together with the municipal utilities, the business park operator, a private service provider or a cooperation.
The most important key partners to operate an overall energy management system of an business park are:
- Landowner / business park operator
- municipality
- energy suppliers (DSOs) (e.g. municipal utilities, private energy suppliers)
- end-users (e.g. business end-user, house owner)
- engineering and construction companies
- service providers

Example: Key partners – Demo Site Hartberg

The most important key partner at the demo-site is the municipal utilities of Hartberg, which acts not only as energy provider and distribution grid provider, but also as owner and renters of the business park. Furthermore, serval tenants in the business park are businesses and companies controlled by the municipal utilities of Hartberg. Hence coordinating local energy generate and sharing it on a peer-to-peer level requires less transaction costs. The public relations are provided by the municipality and its utilities while construction and maintenance are coordinated by a engineering and planning company also under control of the utility. Thus, the municipal utility, as a kind of one-stop shop, also provides the overall energy management concept and services.

Mission model

What are the needs? How is value created?

Economic, social and environmental needs

- Independent, cost-effective and sustainable delivery of heat and electricity
- Promotion of sustainability and regional attractiveness

Beneficiaries / Stakeholder

- Property owner
- DSO / District heat provider
- End-users
- Facility manager, Municipality,
- Engineering company, Construction company, Service company, Service staff

Value Propositions

- Business model
- Reliable and economic heating and cooling supply
- End-users loyalty
- Increased attractiveness for the beneficiaries

Collaborative / Cooperative Business Model(s) along the value chain Local Grid Operator: operate the low voltage grid efficient
Municipality: provision of land and resources, compensation through tax revenues and possibly rental fees
Engineering and construction company: design and construction of the system
DSO: operate and maintain grid, deliver energy to the costumers
Service company: maintenance of the energy system, carrying out repairs
Service staff / Municipal utilities: "care-taker" role as well as energy provider of the end-users. Gain knowledge about load shifting potential, opportunities to set up variable tariffs schemes and demand for innovative business models

Tenants and End-user: Independent cost-effective and sustainable delivery of heat and electricity by using load shifting potential for demand side management purposes.

Example: Economic, social and environmental needs – Demo Site Hartberg

As the city of Hartberg has realized the danger of the regional and local effects from global warming it promotes sustainable settings such as at the demo-site. That's why the local companies at the business park could do peer-to-peer energy trading supported by the local utilities even if that's against their own business. The municipality also promoted renewable energy plants for power and heat generation and charging stations for electric vehicles powered by PV plants. The solution simultaneously fit the objective to a low environmental impact and enrich the community socially due to more sustainable companies and serval events to let people participate at the plans of the municipality.

Example: Collaborative Business Model – Demo Site Hartberg

The municipality needs to have a vision and commitment to protect the climate including the reduction of CO2-emissions. The development of the business park is related directly to the management of municipal utilities and the related city strategy. By hosting research and firms dealing with environmental-technologies such as greening of economy could also improve the awareness to be part of regional and environmental strategy.

Framework conditions for adoption and replication

Market regulations
The energy regulator plays a major role in this use case by setting rules for the operation of the power grid and defining rights and obligations of the grid operator. Today, most players in the energy market are in a competitive situation, which can jeopardize some business models like peer-to-peer exchange of electricity. Thus, in unbundled settings exceptional contractual arrangements between different businesses are needed, if the use case is to be replicated. The creation of regulation innovation zones (regulatory sandboxes) is seen as a good opportunity to speeding-up market uptake, while enabling regulatory bodies to allow for the testing of various temporary schemes and mechanisms.

Financing
This use case builds on existing power grids and energy assets. The most significant investment to be made are the energy management platform and adaptations to make device flexible to price and control signals. Cost savings can be achieved by fostering collaboration between local technology providers and energy utilities. Investment in new and additional infrastructures, e.g. DC direct lines between PV and specific end-user appliances would require stable legal conditions and long-term contractual arrangements.

Social acceptance
Social acceptance of a broader public is of less importance, as main relations are set between businesses. However, active collaboration between the municipality, the energy utility, end-users and local technology providers to develop innovative solutions to the benefit of the local economy. A transparent and clear public communication that provides feedback on a regular basis and helps attracting new customers.

For tenants, it is important to implement cost-effective technology with proven technology. To attract tenants, the system must be simple and operate by itself.

An effective optimisation of energy management might require a "care-taker", with high social competences, who coordinates the complex network of stakeholders and actor groups around the use case. He/she should play a key role in developing a shared vision between stakeholders and helps to identify win-win situations.

Identified barriers to replication and scalability

Technology Level
Technologically the use case is feasible with market ready solutions. Energy management systems developed for industrial companies can be extended and applied to a district or a business park. However, national and local regulations must be carefully examined as they may hinder the provision of certain services to end users.

Market level
For replication and upscaling, one of the critical conditions seems to be the "bundled" context as Hartberg's local grid is operated by its own energy utility, Stadtwerke Hartberg, which is also the energy supplier at the same time.
Energy regulator have to set the rules for the monopolistic grid operator's rights on the one side and on the other side, its obligations. An example from the business park is set up of a direct line for peer-to-peer exchange of electricity. Depending on the country the monopolistic distribution system operator could have the right to forbid two grid-users to exchange energy through the electricity grid or to build a direct line. Thus, many aspects of the pilot project, need exceptional contractual arrangements between different businesses in unbundled structures. Otherwise, the transaction costs often increase and business model of the use case is less attractive or at all impossible.

Stakeholder Adoption level
If the solutions deployed are too complex and expensive and effective maintenance is not ensured, this can lead to a loss of customer confidence and damage the reputation of companies involved in the use case. Data security and protection is also an important aspect to be considered.

Example: Replication – Demo Site Hartberg

Not all components of the use case implemented in Hartberg may be replicable to other business parks. However, some standard technologies such as car charging stations, the energy management platform and demand response technologies implemented on site can be easily replicated in other sites without much modification. Other services like peer-to-peer exchange of electricity may not be applicable in all countries depending on local regulation.
The local context and resources of the area, city or region where the use case is to be replicated must be considered. This has a major impact on the technologies and flexibility services that will be provided to the end-users and the local grid operator.

3 Use Case #3 in Flexible Smart Grids: District Heating load management

This use case describes how smart grid technologies can be used by district heating utilities to shave peak loads in a district heating network. Such load management can be achieved by using the heat storage capacity of building structures to slightly overheat the building in advance of an expected peak. What is required is the thermal capacity of the buildings to predict district heating peak loads in advance, smart building gateways which interact with the building energy management system and a smart grid IT platform which can also be integrated with smart electricity grid functions.

Keywords
District Heating Network, Building Energy Management Systems, Load Shifting

Abstract – Demo Site Hyllie MALMÖ

In the new urban district Hyllie in the city of Malmö, Sweden, a smart grid platform has been implemented which in the longer term will integrate both, the electricity and the district heating network. Currently, the system is mainly applied to manage heat loads of the district heating system by using building structures for heat storage.
Hyllie is Malmö's largest development area and will in the final phase comprise around 9000 new homes and an almost equal number of office spaces. Hyllie is seen to be a 'lighthouse' for Malmö's target to become 100% renewable by the year 2030 as laid out in a climate-contract between the city of Malmö and the companies VA Syd and EON.

Image 1
Control unit used in Demo Site Hyllie
(Source: ReFlex website)

Image 2
Focus areas of the Demo Site Hyllie
(Source: ReFlex website)

Use case outline
The Flexibility Challenge

Scope and objectives of the use case
This use case may be applied in all district heating networks with a need to shave peak loads. Such load management reduces the need for heat generation with back-up units, which are in many cases fossil fuel based, e.g. natural gas or oil burners. Load management reduces the level of back-up capacity required and the hours of use of such units and thereby helps reduce the climate gas emissions of district heating as much as it is improving its economic viability. What is required for this use case is a working interface with building energy management systems and the cooperation of property owners or facility managers.

The objective of this use case is to supply as many households and businesses as possible with affordable and sustainable heat in winter and/or cooling in summer.

Narrative of the use case
The main precondition of this use case is the existence of a municipal or local district heating network – which can be both publicly or privately owned and operated. Moreover, an integrated heat supply system is required, where the network owner/operator and the heat supplier are identical or can cooperate closely. Currently, most district heating systems are not unbundled which means there is no strict separation of a monopoly network operator and competitive heat suppliers as is known from deregulated electricity systems.

Moreover, close cooperation with property owners or facility managers is necessary. They need to accept the interaction of the district heat supplier with their building energy management system which has to be externally controlled to intercept a peak in the DH system. Large property owners and operators, such as municipal housing companies, are advantageous. It reduces financial and administrative burdens compared to multiple contracting parties and increases the chance for similar energy management systems to reduce installation and maintenance costs. The heat provider must install a smart communication interface in each building which can interact with the specific characteristics of the energy management system applied in the building.

Sometimes in advance of a district heating supply peak the district heating operator sends a signal to the building energy management systems to raise the temperature level of the buildings beyond the current target. Temperature rises within a small range, around 0.5 – 1 degree, are barely felt by the building users. At the time of the district heating peak, i.e. high demand for district heating from users, the supply of the 'over-heated' buildings can be reduced and shifted to other customers, bringing the originally over-heated buildings back to their original level or even slightly below. If the overall heat demand goes back to a normal range, all buildings are heated at their target level.

In the smart district heating system applied in several places by e.on Sweden, the business model currently builds on the participation of building owners without financial compensation. However, small fees for the use of the building energy management for district heat management purposes are possibly viable.

What can be replicated? How could this be achieved?

What to do as Municipality?

- Develop sustainable heating and cooling strategy for the municipalities in cooperation with relevant stakeholders; include options for better DH load management and thus more efficient operation of the DH system in the municipal strategy.
- Help to motivate building owners to participate and create a favourable environment for the use case.

What to do as actor in the Energy Sector?

- Attract building owners who are willing to participate in the heat load management system
- Cooperate with the municipalities and environmental initiatives to create a favourable environment for a more sustainable smart district heating system
- Provide examples of working cases of the management system to create trust and show that building energy management systems are not negatively affected by the external intervention.

What can be replicated from Demo Site Hyllie MALMÖ?

The use case which can be replicated from the example in Hyllie is a smart grid platform for the load management of district heating with an IT infrastructure for control and prediction of heat loads and special devices interacting with the building energy system to store heat in the building structure in advance of peak load of the district heating system.

Despite some technical limitations (control infrastructure needs to be built up; interfaces with building energy management systems and their technical specifications need to be developed and are currently not commercially available), only a few pre-conditions appear to be critical for replication or upscaling of this smart grid solution. Such solutions are only relevant for cities with district heating systems (and preferably in situations where a reduction of peak loads is useful, e.g. by reducing the need to increase the capacity of heat pipes despite the expansion of the DH system) and only buildings with an energy management system can be integrated.

Integration of network ownership and supply are a precondition, but this is usually the case with district heating systems. Public ownership is not a requirement, but a cooperative relationship with building owners is essential because they have to voluntarily accept the installation of such a system in their building without financial benefits (otherwise the business case for this solution might be in jeopardy). It is thus also of advantage to have only a limited number of building owners as contract partners in the supply area. As has already been tested by e.on the system is scalable and can also be applied to the existing building stock and replicated in other cities.

Context conditions

Assumptions
It is assumed that a reduction of district heating peak loads improves both, the environmental and economic performance of the district heating system. Moreover, the agglomeration of buildings in question, whether in an urban or more rural context, needs to be supplied by a district heating grid and needs (in a sufficient share) to be equipped with building energy management systems. As there are no off-the-shelf solutions available, the heat supplier needs to be sufficiently competent in developing interfaces with the building energy management systems and integrating these in a joint IT platform (e.g. smart grid platform).

Geographic and Environmental Conditions
The system is easily scalable and can be implemented in both, new buildings and the existing building stock. The dimensioning depends mainly on the dimensions of the district heating system with its requirements of heat supply densities. Constant maintenance and proper operation of the system are obviously of crucial importance and might otherwise result in reduced comfort levels of building users. Beyond this, environmental damage from operation problems cannot be expected.

Prerequisites
Framework conditions and prerequisite which make the implementation of such systems easier are favorable municipal planning contexts, e.g. a municipal energy or climate plan, which request sustainable heat supply solutions and provide a sufficient motivation for actors, such as property owners, to cooperate in this effort to reduce heating network peak loads even without monetary compensation. Moreover, an ownership structure of buildings connected to the DH system with a small number of building owners and preferably with a limited number of types of building energy management systems significantly reduces transaction costs for building up a smart district heating grid.

Legal and Ethical Considerations
All relevant legal guidelines of the country must be observed, as well as all contracts with property owners must be legally completed; for this, a lawyer for contract law must examine the documents and release to the legal correctness of the contracts and to avoid complications.

Key Performance Indicators (KPI)
Relevant KPIs for the optimization of district heating systems also apply in this use case (see Cortés, 2015: D 2.1. of Horizon2020 project Optimisation of District Heating & Cooling systems). Such KPIs include 'reduced energy consumption', 'reduced peak load' (aggregated peak load, discrete peak load or singular peak load), 'user thermal comfort flexibility' (referring to the thermal comfort zones of users in buildings) as well as 'economic benefit'. Appropriate algorithms to specify and calculate these performance indicators need to be developed in concrete cases.

Context conditions – Demo Site Hyllie MALMÖ

The model is embedded in a broad partnership of the municipality, e.on as the owner of the district heating system and heat provider, and municipal or private building developers and owners. A foundation for these collaborative relationships is the Climate Contract and Hyllie Environmental Programme as well as a long tradition of collaborative public-private partnerships for the provision of different types of infrastructure services in Malmö municipality.

Local energy system and stakeholders

Local grid infrastructure
The local grid infrastructure consists of a local/municipal district heating network supplied by a sustainable energy source. The district heating grid is connected to a sufficient number of buildings with building energy management systems. In addition to the district heating grid, the buildings have to be integrated with a smart grid IT platform which interacts with their building energy management system through a smart gateway and allows the heat supplier to take influence on the building temperature level controlled by the BEM system.

Generation and storage
Generation is not specific to the 'smart' district heating system which builds on a traditional district heating system and its heat generation. However, in the best case, the need for peak heat generation capacity, e.g. through gas boilers can be reduced. Heat storage is provided through the existing building structures and does not need separate storage provisions.

End-user components "behind the meter"
No additional installations are required at the user side / behind the meter as the user does not need to intervene in the system actively and should not feel a difference in heat supply with or without peak load mana-gement, in terms of thermal comfort.

Actor-groups and Stakeholders-groups (third parties, ownership)
Important key actors are:

- district heating system operator – public or private utility
- property owner / facility manager
- Users of buildings, e.g. households or offices, do not need to actively participate in the system.

Local Energy System – Demo Site Hyllie MALMÖ

The system is applied to manage heat loads of the district heating system by using building structures for heat storage. In the longer run, the aim is to develop a smart grid platform operating across the heating network and electricity grid. The main feature of the smart district heating system is a smart residential gateway (control box with mini-computer) connected to the building management system in district heat supplied buildings and allowing to use the building structure as heat storage by slightly overheating the building in advance of expected peak demand. In the longer run, the residential gateways can be used to provide other types of smart grid functionalities to the buildings and households.

Key partners – Demo Site Hyllie MALMÖ

The key partners in the demo site Hyllie, a new-built urban district in the Swedish city of Malmö, are the international energy utility E.on, which in Malmö operates the district heating network and supplies heat to a large share of properties in the city, as well as property owners, in the first place the municipally owned housing company, but also private property owners. The municipality is essential to provide an appropriate context, e.g. through the municipal environmental program in Malmö, which creates (non-financial) incentives for property owners to cooperate with the municipality or district heating system operator.

Mission model

What are the needs? How is value created?

Economic, social and environmental needs
More cost-effective and sustainable delivery of heat in winter, or cooling in summer through the reduction of peak load costs (additional peak load boilers and generation; avoided costs for the capacity increase of pipes).

Beneficiaries / Stakeholder
- Local electricity grid operator / District heat provider
- Grid users / heating network users
- Property owner
- Facility manager, Municipality, District heat provider

Value Propositions
- Business model
- Reliable and economical heating and cooling supply
- End-users' loyalty
- Increased attractiveness for the beneficiaries

Collaborative / Cooperative Business Model(s) along the value chain
- Property owner: provision of building as heat storage, providing access to building energy management system
- District heat provider or IT company: design and construction of the system
- Local electricity grid operator / District heat provider: operate the district heating network and smart management system, deliver heat
- Service staff / District heat provider: contact to end-users, service delivery
- end-users: customer of the services offered, cheaper and more reliable heat supply

Economic, social and environmental needs – Demo Site Hyllie MALMÖ

Sustainable development and the mitigation of climate change are crucial elements of the vision of an integrated energy system in Hyllie, and the smart grid development is regarded as a part of that aim. The macro-economic effects are based on the reduction of peak production – thus reducing costs due to climate emission taxes and fuel prices. A broader installation of load management would have further potential and is currently implemented also in existing residential areas in Malmö and other Swedish cities.

Collaborative Business Model – Demo Site Hyllie MALMÖ

The energy infrastructure has been privatised since 1991 and is now owned by the German company e.on. The municipality and energy company are however cooperating closely on many issues, and especially in the Hyllie project – e.on as the owner of the district heating system and heat provider, and municipal or private building developers and owners.

Framework conditions for adoption and replication

Market regulations

District heating networks are only lightly regulated in most European countries. Some countries e.g. have regulated heat energy prices. So far, DH systems are fully integrated, i.e. there is no regulatory and ownership separation between the heating network and the supply of heat. However, EU's Heating and Cooling Strategy (COM (2016) 51 final) and the so-called winter package (clean energy package) include provisions for third-party access to the DH network for renewable heat producers. These strategies have not yet been transposed into national laws and moreover include provisions for certain exemptions to third-party access. Thus, the use case for smart district heating networks with load management which builds on the integration of network operation and heat supply should be applicable in most European Union member states.

Financing

The use case builds on existing heating networks which also do not need upgrading to comply with the smart load management strategy. For the time being the primary funding barrier appears to be the development and programming of smart gateways as interface of the smart grid platform and the building energy management system as well as the IT platform for smart grid load management. Currently, there is no commercial product available. E.on Sweden has developed such systems for their use and start to roll them out in municipalities where they operate the district heating network.

Social acceptance

In the applications of the use case so far, social acceptance of tenants in buildings has not been a discernible issue, as people living in the respective buildings or working in offices there should not feel a difference with or without the load management system. Also, the installation of the smart interface with the building management system is limited to the control system of the building and does not require any construction work. Acceptance is however required from the property owner or facility manager which so far has not been a severe problem. Acceptance can be further facilitated by a municipal setting where the cooperation of district heating providers and building owners is encouraged and part of municipal energy and climate strategy. Information material and events to the building occupants will further increase their support for the load management systems, particularly if embedded in a strategy for increased energy efficiency and low-carbon heat supply.

Identified barriers to replication and scalability

Technology Level
As pointed out above, a significant technological barrier is that no such interfaces between the district heat provider and the building energy management system (smart gateways), nor an IT system for smart district heating networks is commercially available at the moment and has to be custom made in case of replication. A further barrier is that these interfaces need to be made compatible with the particular building energy management systems implemented in the buildings which should become part of the load management system.

Market level
In the case of smart grid applications in Malmö, Sweden, the smart district heating load management system was the only part where a viable business case could be developed under current conditions. Installation and operation costs of the system are outweighed by the savings achieved through load management. This situation may change if building owners request fees for their participation in the load management effort.

Stakeholder Adoption level
A challenge is undoubtly to install the heating network load management in a sufficiently large number of buildings connected to the district heating network. Benefits of delayed (or avoided) network capacity extensions of the provision of back-up heat generation capacity require a certain level of storage capacity in the buildings which are part of the system (depending on the specific situation in the network in question, such as number and height of peaks, network capacity limits). Recruitment and motivation of building owners to participate in load management is thus an essential part of the use case. A further precondition for the adoption level is the availability of an interface for the technical specifications of the building energy management systems of DH users. If only part of the buildings can be connected for technical reasons, the adoption level remains proportionally lower.

4 Use Case #4 in Flexible Smart Grids: Shared use of local low temperature resources

The use case describes how a municipality could enhance its attractiveness to new citizens and promote development areas by using a sustainable heating concept. A medium sized decentralised thermal energy source feeds a local heating network, which distributes heat to individual end-users. Each end-user utilises a heat exchanger, mostly a heat pump, for cooling and heating its building. With only one energy source a large area can be supplied. Also, the network acts as a thermal storage system.

Keywords
Municipality, Low Temperature, Heating Network

Reference – Demo Site Güssing

In Güssing, a biomass plant supplies heat to a district heating network with a length of about 35 km and more than 85 end-users connections. Customers are private households as well as industrial end-users. Biomass is provided by regional farmers, foresters and the local parquet industry (sawdust and waste-wood). In total, three large heating plants are connected to the heating network, of which two are currently in operation. These primarily supply the city of Güssing and the region around the power plants with thermal energy. Outside Güssing there are some other small district heating networks for local heat supply. This system configuration allows minimising distances between heat production and supply, thus keeping heat losses as low as possible.

Reference – Demo Site Wüstenrot

An agrothermal heat collector serves as a thermal energy source to supply heat to a low-temperature district heating network. The heating network is connected to a development area in Wüstenrot nearby an agricultural area. The end-users are single-family houses equipped with heat pumps. The heat pumps extract energy from the low-temperature network and transfer it into the buildings. They are powered by the electricity grid and local PV power plants. The key partners in Wüstenrot are the municipality and its utilities (energy supplier). Both are responsible for public relations, primarily to promote the solution and its benefits to the end-users. Furthermore, the municipal utility has to acquire customers and negotiate with landowners. The technical construction and services are performed by subcontracted engineering and constructing companies.

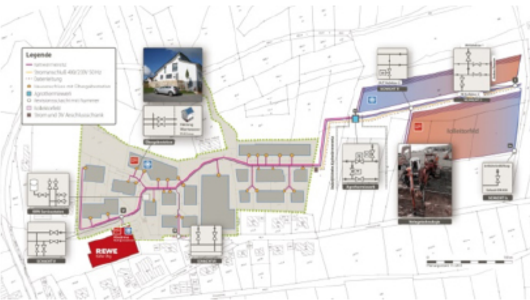


Image 1
Planned heating network Wüstenrot
(Source: ReFlex website)

Image 2
Plus-energy residential area ‚Vordere Viehweide'
(Source: ReFlex website)

Use case outline
The Flexibility Challenge

Scope and objectives of the use case
This use case is suitable for areas with an available decentralised low-temperature heat resource nearby. The advantage of a shared local low temperature resource is the use of (process) heat at low-temperature to feed the thermal network, which otherwise remains unused. Thermal energy is often available, e.g. from the environment (ground/air) or generated as an unused by-product in many industrial processes. Any source of thermal energy with enough power to heat the transfer medium to a specified temperature level can be used.

The objective of this use case is to supply as many end-users as possible with cheap and sustainable heat in winter and/or cooling in summer.

Narrative of the use case
In rural areas and districts with a low population density, the heat demand is much lower than in urban districts. Distribution losses and high investment costs for the network infrastructure impeding the profitable operation of a traditional heating network based on a large-scale heat generation unit. Instead of using individual heat generation units, local low-temperature resources may be shared. A medium-sized heat generation unit distributes thermal energy through a local heating network to connected households. Each household operates a decentralised heat pump to increase the temperature level to meet the individual demand. Assuming a coefficient of performance (CoP) of up to 4.0 for the heat pumps a significantly reduced energy demand may be achieved compared to individual central gas or oil heating.

What can be replicated? How could this be achieved?

What to do as Municipality?
- Identify potentially usable low-temperature heat resources (e.g. agrothermal, geothermal, waste heat)
- Clarify legal requirements for the implementation and operation of a local heating network
- For (new) development areas, consider the implementation of a heating network at an early stage of planning
- Raise the attention of potential customers by informing and involving them from an early stage onwards

What to do as actor in the Energy Sector?
- Attract a critical mass of end-users to connect them to the heating network
- Provide a sufficiently large sustainable heat source that can supply enough heat to connect (additional) end-users
- Provide service to customers (e.g. long-term contracts, maintenance)

What can be replicated from Demo Site Wüstenrot?

To replicate this use case like it is applied in Wüstenrot similar boundary conditions are substantial. An agrothermal collector can only be installed if there is appropriate space close-by and the municipality or property developers can acquire the right to use it in the long term. Having the opportunity to install an agrothermal collector, sufficient load has to be connected to operate a profitable local heating network.

Context conditions

Assumptions
It is assumed that the residential area already has a heating network, or it can be installed. It is essential to be aware that a subsequently installed heating network generates excessively higher project costs. Depending on heat generation and installation costs there are a minimum number of end-users for a profitable heating network. The higher the connection rate of households the more profitable is the system. In new development areas, a general obligation to connect to the heating network may be considered.

Geographic and Environmental Conditions
From an environmental point of view, the heating network does not present any danger to the environment during normal operation. However, in the event of a leak, an environmental impairment must be considered, and an emergency plan is obligatory.

Prerequisites
The prerequisite for optimal planning and operation of the heating network is that the designated area, which has to be supplied with heat, is located close to the heat generation unit to minimise heat losses and costs. To achieve high availability of the heating network, operation and maintenance of the system play a key role but can be performed by the manufacturer himself or an external service company.

Legal and Ethical Considerations
All relevant legal regulations of the country must be observed, and all contracts must be legally concluded. A lawyer or legal expert must examine carefully each contract to avoid any further complications between the involved parties.

Key Performance Indicators (KPI)
In this use case, several KPIs are used to represent the performance of the low-temperature heating network, such as Seasonal Performance Factor (SPF) and the return in terms of profit in relation to the capital, also called ROI (Return on Investment).

Key partners – Demo Site Wüstenrot

The outskirts of Wüstenrot are close to agricultural land. The municipality as the landowner was willing to provide its nearby field for heat exchange purpose. Thus, an installed agrothermal collector feeds heat to a new development neighbourhood utilising a low-temperature heating network. As the municipality and its utilities made a significant effort on engaging people, all private household are connected. Electric heat pumps use the low-temperature source for cooling and heating the building and for hot service water. Thermal storages and roof-top photovoltaics complement the system.

Local energy system and stakeholders

Local grid infrastructure
The local energy infrastructure consists of a local heating network for heating and cooling, connected to a sustainable energy source as well as the local electricity grid. Each house has its connection to the district heating network with an electric heat pump to transfer energy from the network to the building or to release thermal energy it into the network for cooling.

Generation and storage
Due to the thermal mass of the heat transfer liquid of the heating network, it can act as thermal buffer storage. By increasing the liquid's temperature within safe boundaries, generation peaks can be buffered in the network. Therefore, excessive thermal energy from the generation unit can be stored in the network itself or additionally in thermal buffer storage systems in the buildings.

End-user components "behind the meter"
An electric heat pump transfers the heat from the heat transfer liquid of the heating network to the internal circuit of the building while also adding more energy and heat to it. This circuit distributes the heat to the space heating units and / or to the air conditioning system. Depending on the installation, the circuit could also feed service water.

Actor-groups and Stakeholders-groups (third parties, ownership)
The operator of the system can be the municipality with the municipal utilities or a private provider. Cooperation is also possible so that for example the municipality operates the heating network but draws thermal energy from a private provider.
The most important key partners to operate a shared local low-temperature network are:

- Municipality
- Energy suppliers (e.g. municipal utilities, private energy suppliers)
- Landowner (agrothermal) / processing company (heat as by-product)
- Grid and heating network users (e.g. businesses, house owner)
- Engineering and construction companies
- Service providers

The task of the operator of a district heating network is not only to supply energy but also includes preventive maintenance and emergency service in case of defects. The operator can be municipal utilities, private service companies or the energy supplier itself. Also, experience has shown that direct communication with the customers is essential at every stage of the project. The communication may be performed by telephone, postal, in person (service staff) or digitally via the internet (online portal, e-mail) and must not be underestimated. Furthermore, sales, dealing with repair services, complains and administration of end-users' data has to be considered to operate a local heating network properly. Energy supply as well as service and maintenance base on contracts between the key partners. This includes long-term contracts between the heating network operator and owner, the landowners, house-owners and engineering and construction companies.

Key partners – Demo Site Wüstenrot

The key partners in the Demo Site Wüstenrot are the municipality as the owner of the land used for agrothermal collectors and its municipal utilities (in charge of electricity grid operation, energy supplier). Both do public relations to promote the solution to interested parties living in new development areas. The municipal utilities are in charge of acquiring customers and negotiating with landowners. Subcontracted engineering and construction companies perform technical construction and services.

Mission model

What are the needs? How is value created?

Economic, social and environmental needs
Independent cost-effective and sustainable delivery of heat in winter and cooling in summer.

Beneficiaries / Stakeholder

- Energy infrastructure operators: energy utility / local heat provider
- Grid and heating network users
- Property owner
- Facility manager, Municipality, District heat provider
- Engineering company, Construction company, Service company, Service staff

Value Propositions

- Business model
- Reliable and economical heating and cooling supply
- End-users' loyalty
- Increased attractiveness for the beneficiaries

Collaborative / Cooperative Business Model(s) along the value chain

- *Municipality*: provision of land and resources, compensation through tax revenues and possibly rental fees
- *Engineering and construction company*: design and construction of the system
- *Energy infrastructure operators*: operate the plant, deliver energy to the households connected to the local heating network
- *Service company*: maintenance of the energy system, carrying out repairs
- *Service staff / Municipal utilities*: first level contact with end-users
- *End-users*: household connected to the local heating network

Economic, social and environmental needs – Demo Site Wüstenrot

As the community of Wüstenrot is a rural area with no nearby jobs, it suffers from migration into urban agglomerations. Attract people by new development areas with prospective low incidental expenses especially for heat due to a district heating network and obligating power generation by PV plants was shown to be a good solution for Wüstenrot. Also, the solution simultaneously fit the objective to a low environmental impact and enrich the community socially due to new young families and serval events to let people participate in the plans of the municipality.

Collaborative Business Model – Demo Site Wüstenrot

While the municipality and its utility have to spend money on service staff for public relation and to interact with the end-users, they also earn money directly by property tax and indirectly by enriching the village with new citizens spending money on local businesses. Besides, municipality, its utilities and the service company are now frequently requested to show the Demo-site to experts from all over the world. The municipal utilities and especially the service company could use their gained expertise for other comparable projects. After the successful realisation of the heating network, other end-users are more willing to participate in new heating networks. This is why another heating network will be realized in the centre of the village with existing buildings and a school centre.

Framework conditions for adoption and replication

Market regulations
District heating networks are not subject to regulation in Germany. The topic of district heating is not part of the statutory scope of the Federal Network Agency. There is also no regulation of district heating suppliers. The Federal Cartel Office is responsible for the protection of competition in the supplier market as an independent competition authority. In 2009, the Federal Cartel Office initiated an investigation of the district heating sector, providing a final report "Sektoruntersuchung Fernwärme" in 2012.[2]

Financing
In terms of financing, first of all, investment costs have to be considered. For a district heating network, these are the costs for engineering and construction companies as well as for technical components and the entire construction material. Secondly, running costs must be taken into account: these costs build up during the entire service lifetime of the system. Some costs such as the routine service are incurred on a regular basis, other, such as spare parts for defect subsystems, are irregular.
HFT Stuttgart, the leader of the accompanying research project "envisage" in Wüstenrot, set up a procedure to develop an appropriate financing concept for low-temperature district heating networks. The main steps are:

1. Energetic-technical analysis to check the basic requirements: survey energetic potential and fields of action, analyses of technical feasibility, definition of measures as well as alternatives and variants, identification of relevant stakeholder groups.
2. Economic efficiency analysis and sustainability analysis as a basis for initial investment decisions: calculation and evaluation of the respective investment volumes and operating costs lead to first conclusions regarding the cost-effectiveness and their compatibility with the objectives of the region.
3. Development of Appropriate Financing Concepts based on the identification of target groups, collection of funding and resources, identification of funding needs and constraints, exploration of funding opportunities and innovative financing instruments.[3]

[2] https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Verbraucher/Energielexikon/energielexikon-node.html
[3] Vision 2020 Die Plusenergiegemeinde Wüstenrot Fraunhofer IRB Verlag ISBN (Print): 978-3-8167-9629-9

Social acceptance
Due to the higher construction and installation costs at the beginning, the initial investment costs might be an obstacle for interested households. Although a connection to the heating network is attractive on a long-term perspective. It has to be proven to the customer that the low-temperature heating technology is cost-effective (robust investment plan including investment and operating costs) compared to alternative heating systems. The new, not yet pervasive coupling technologies such as photovoltaic based heat generation can also be a reason for a somewhat cautious attitude of people towards solutions based on local heating networks. Therefore, it is necessary to promote the concept of low-temperature heating networks and actively involve interested users, e.g. through information events and site visits.

Identified barriers to replication and scalability

Technology Level
There are many solutions for low-temperature heating networks on the market. However, every solution has its specific framework conditions which makes it difficult for replication and upscaling. However, using an agrothermal collector and a low temperature is successful for regions with seasonal temperature variation as it deals with heating and cooling the buildings. Furthermore, it could shift the resaved heat from the buildings in the summertime to the autumn due to the inertia of the soil.

Market level
The major challenge is to find the best solution and suitable area for the energy resource, which should be preferably close to the end-users' premises to minimize heat losses and costs for the heat network. For maintenance, the service staff need to be trained on the individual heat generation unit, the heating network and the heat exchangers of the end-user. It can be assumed that every local heating network differs in its structure, scope and technology. Furthermore, it is crucial to demonstrate the added value and prospects of low-temperature resources to (new) customers. This includes the supply of energy around the clock at a reasonable price and fulltime service. The added value for the municipality is an increase of attractiveness of the development area as the local heating network provides thermal energy with a simple, low-maintenance and sustainable solution to the households.

Stakeholder Adoption level
Another challenge is to convince as many households as possible to connect to the heating network and give up their old heating system. After finding a suitable heat source, one of the main obstacles for the energy supplier is to acquire enough customers. Therefore, it is important to have service staff trained to advise and recruit. Based on experience a good communication concept is essential for good user acceptance. Especially good communication between customers / households on the one side and service provider(s), heat supplier, municipality and municipal utilities on the other side is important to make the service smooth, effective and sustainable.

Technology Level – Demo Site Wüstenrot

Currently the agrothermal technology is still at the level of an early commercial deployment, there are a few agrothermal collectors in operation. There are still many research topics to be observed. On example are the effects on plants growing on the fields above the collector. Also, there is a lack of information about long term operation as the technology is relatively new.

5 ReFlex Toolbox

Replicability tools for target groups

Introduction

The successful replication of smart grid projects can be supported by specific tools in order to facilitate the implementation of solutions within new settings and in new areas. However, different target groups, different socio-economic or spatial settings and the various project phases may require different tools for upscaling and replication. ReFlex differentiates between 5 phases within the replication process (see figure "Overview ReFlex Tools" below) that cover the whole process starting with the search for ideas; the planning and analysis of the replication project; the actual implementation phase as well as lessons learnt from own and other Smart Grids projects. The ReFlex Guidebook presents some major methods and tool to support replication within those different phases (for example, the ReFlex CoP can support the finding of initial ideas, provide lessons learnt as well as reducing barriers and opposition for implementation of the replicated solution; whileas the ReFlex-Box is mainly addressing the planning and analysis phase of a replication process).

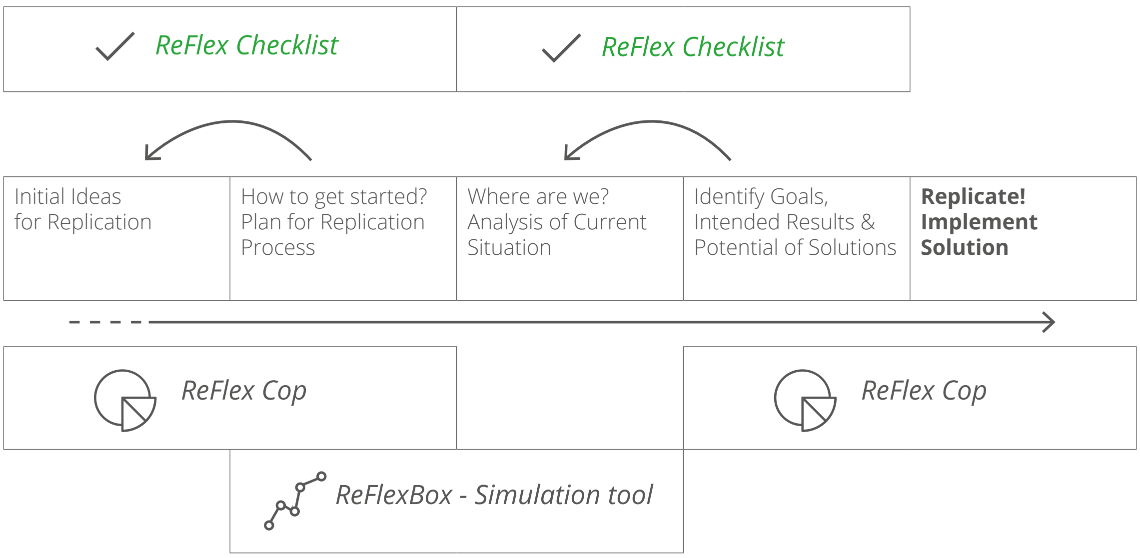


Figure 1
Phases within a Replication Process and the ReFlex Toolbox

Checklist for the evaluation of context factors for successful replication

Introduction
If you intend to transfer one of the use-cases to a replication site, the following checklist helps to identify the critical context factors to be considered. Not being able to answer all questions with yes must be expected. If answered with NO, you might have to reconsidered to replicate the use-case at all. Other questions, if not answered with YES, leads to further investigations how context conditions can be changed, and which measures could be taken to replicate the use-case.

Please consider that the list is not encompassing all factors which might be encountered in replication. However, it provides a systematic overview of the most relevant dimensions and context factors identified by practitioners in the ReFlex project.

Table 1: Checklist

	Questions
Space and Geography	Are relevant geographical and climate conditions similar? Are the spatial scales and dimensions applicable to the replication site?
Technical functionality and technology	Can the same technological components be implemented? Can the same digital control, information and communication hardware and software applications be implemented? Is the relevant technological know-how available among the partners in the replication project, or can it be acquired?
Economics and Sustainability	Is there a profitable business case for all private and public economic actors involved? Are the right economic actors involved? (public and private investors, energy infrastructure owners, energy system businesses, end-users as consumers and producers) If end-users are involved, are their economic benefits clear and transparently communicated? Is there a clear analysis of risks and uncertainties and how the consequences are shared among the partners in the replication project? (e.g. consequences of hacking, sharing of losses) Can the replication be financed by the actors involved, and/or is it bankable? (public and private investors, energy infrastructure owners, energy system businesses, end-users as consumers and producers …) Does the use-case make sense from the economic perspective for the municipalities and/or regions affected by it? (e.g. local value added, local employment, tax revenues) Does the use-case, once transferred to other sites in the same country and beyond, have the potential to provide benefits for the whole economy, in terms of value added and employment? Does the use-case, once transferred to other sites in the same country and beyond, have the potential to provide benefits for the decarbonisation of the energy system at large?

Institutions and Regulations	Do the same national legal frameworks and standardisation rules apply? a) requirements for unbundling of energy supply and grid operation and energy market regulation (not all the same under EU regulation) b) tariff models for end-users c) grid codes (e.g. allowing for DC grids or direct lines) d) rules for licencing of distribution system operation e) data protection and privacy regulations Are the energy market institutions comparable? a) room for local energy utilities (e.g. Stadtwerke) to act as grid operator, energy supplier, energy producer, storage provider b) room for local energy exchange in “citizens energy communities” or business-to-business cooperation Does the state provide (soft) measures to foster the integration of renewable energy sources and flexibility services? a) regulatory-body’s legal space for allowing replication projects (e.g. regulatory sandboxes) b) requirements for climate and energy strategies and implementation plans c) regulators’ possibilities for accepting Capex and Opex for grid tariffs
Social and political visions, practices, networks and culture	Do actor and stakeholders share a vision on how to achieve shared goals by the intended replication, be it explicit in the form of a formal political agreement or an implicit or explicit strategy? Are the benefits of the use-case for third parties (neighbours, citizens, competing businesses) explicitly or implicitly considered in a mission model? Are the actors and stakeholders convinced of the values and benefits of the use case in terms of economic, ecological and social sustainability? Is the network of actors involved in the replication project robust for long term commitment? (joint investments of businesses, households, public-private partnerships) Do establishes practices and behaviours of end-users exist, on which to build on? (e.g. demand response tariff-schemes) How developed is the trust between actors and stakeholders? (e.g. trust in state institutions regarding private data, ICT security) Would the use-case also work if this trust is shattered?

ReFlex - COP Community of practice as learning tool

Why repeating mistakes others already paid for?
Many projects dealing with flexible and integrated Smart Energy solutions share similar challenges when in the phases of (a) Identifying initial ideas for the right solutions, (b) Selecting and deciding how to get started, and (c) Final decision-making how to implement the replication project. At the same time, many obstacles and opportunities are similar, although most likely there are differences in technological components used, as well as in how the solutions are embedded in a socio-economic environment. Therefore, exchanging experiences with other practitioners helps to enlarge the knowledge on success factors and – foremost – how to avoid costly mistakes, for which others already had to pay for. One of the most appropriate Learning Tool, which considers those aspects, is a Community of Practice:

What is a Community of Practice?
A Community of Practice is a group of practitioners, who share the same interest and challenges in a specific area. Through a moderated process of sharing information, expertise and experiences, members learn from each other for tackling their challenges and can develop personally and professionally.
To get communities going and to sustain them over time, it is crucial that participants regularly meet and discuss shared challenges and try to find practical solutions.

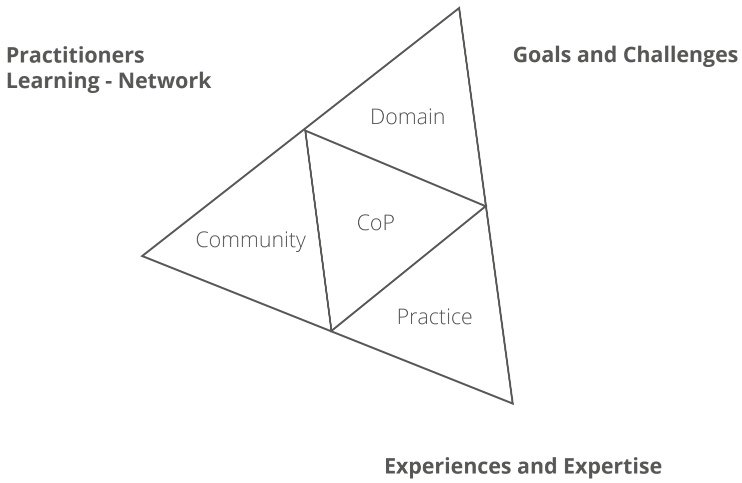


Figure 2
Key Element of a CoP

The Community of Practice in ReFlex

In the framework of the ReFlex project, the main purpose of the CoP was to foster knowledge exchange, learn from the experience in the Smart Grid demo regions and discuss issues encountered during the project implementation phase and challenges related to the transfer and/or replication of the tested solutions to other sites.

Resources – The CoP included 7 site-visits, three of them back-to-back with the CoP workshops, which were held in Austria, Switzerland, Germany and Sweden in a period of 2 years. The events were organised by the local project partner and had up to 30 participants.

Main activities – CoP workshops were prepared based on practitioners' questions regarding ongoing and emerging challenges. These were collected in interviews and sessions of previous CoP workshops. Thus, working groups with dedicated subjects were prepared with inputs from the project team's experts and designed for exchange and discussions among practitioners. Pressing topics included the profitability of flexibility services, cooperative business model development and changes in markets structures. Also emerging topics such as the role of distributed ledger (blockchain) technologies and expected regulatory changes trough the energy policy framework "Clean energy for all Europeans" (winter package) were discussed.

Main outcomes – Practitioners' mutual learning on the trustful atmospheres was highlighted as main benefit. This included learning from successful and failed projects and from trying to understand the reasons behind it considering the various context conditions (e.g. what difference it makes when you compare innovation potential for grid operators in unbundled and vertically integrated market structure). The intensive workshops also provide legitimacy to the recommendations out of the ReFlex project such as the need for experimental space in sandboxes or regulatory innovation zones.

CoPs are not yet commonly recognised as highly effective for replication and rarely financed with public support. Hence, those in need of such learning experiences, should consider it as a tool of choice and should request from the funders of replication projects to provide this opportunity and to search for a critical mass of practitioners to establish such learning-networks.
Peculiar aspects of a ReFlex CoPs as learning tools between demo site- and replication practitioners – Deep-diving into demo site experiences are valuable sources for replication processes. They help to learn about the technological and functional aspects off use cases as well as the collaborative aspects of innovation process and business models and allow to investigate the similarities and differences in the context conditions of each use case. CoPs as interactive tools help to learn from good practice as well as from the failures. In the trusted atmosphere of CoP workshops individual and group knowledge can be generated and applied in the planning, decision making for replication projects as well as during the co-creative implementation process.

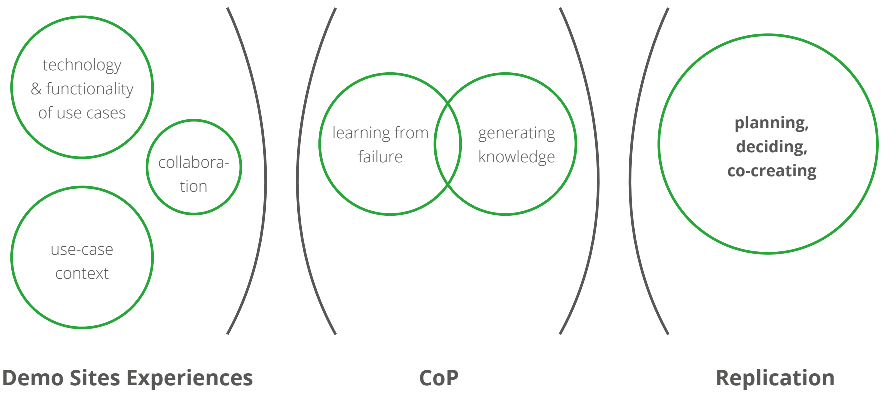


Figure 3
ReFlex CoPs as Learning Tools between Demo Sites and Replication

RefleBox simulation tool
The Flexibility Assessment

The ReFlexBox Tool
The ReFlexBox tool simulates the operation of energy systems, consisting of single buildings located in the same grid area. The tool assesses the flexibility potential of the designated area to optimize and scale up best practice technologies. The replicability potential is based on experiences obtained in various smart grid demonstration projects of the ReFlex Project.

The ReFlex tool can assist cities and districts in planning their local smart grid infrastructure by replicating smart grid solutions from existing demo-sites and scaling them up to the desired size. Each building in the model has a heat pump with thermal buffer storage for space heating and a boiler with a hot water tank to supply domestic hot water. Furthermore, a PV plant with a battery storage system supplies power to electrical loads. The energy system operation is simulated on both, building and district level.

Flexibility potential of the energy system is defined as a power adjustment kept for a period without influencing the comfort level in the buildings. The flexibility potential of the replicated and scaled-up system is quantified in the simulation. For comprehensibility, the results are translated into the number of additional electric vehicles that can be implemented on the site using statistics but without the need to enhance the energy system.

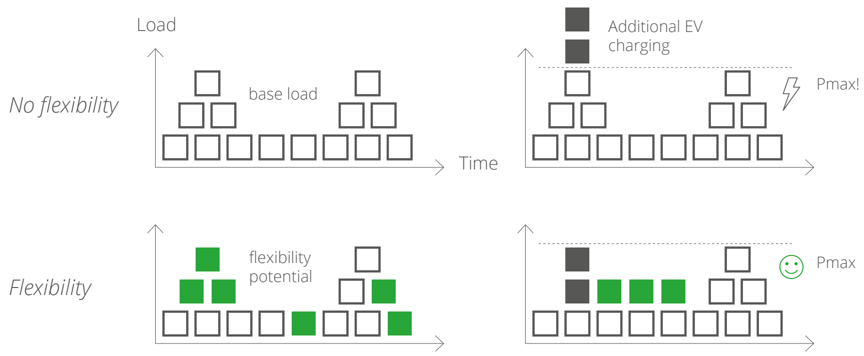
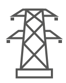


Figure 4
Plus-energy residential area ‚Vordere Viehweide'
(Source: ReFlex website)

Target Groups
ReFlexBox supports multiple stakeholders involved in smart grid projects:

Decision Makers
Decision makers to understand better energy systems and the benefits of flexibility provided by controllable loads and decentralised generation units. During the simulation, users can observe the operation of the onsite energy system over time. Yearly energy system performance and overall flexibility potential are assessed and visualised.



Local electricity grid operator (DSOs, local energy utilities)
Local electricity grid operator, e.g. Distribution System Operators (DSOs) or local energy utilities, interested in solutions of demand-response-related questions, such as, to which extent load management can be reasonably done, by quantifying the amount of flexibility offered from the energy system.

Local authorities
Local authorities can assess the feasibility of replicating or scaling-up a demonstration smart grid project by modifying inputs such as weather conditions, number of households.

Simulation Framework and Input Data

Current replication and upscaling are based on measured input data of the Biel-Benken demo-site in Switzerland. A demo version of the ReFlexBox is available online, which allows running two preset cases, at following link:
https://bit.ly/2GcMXZJ
A full version of the ReFlexBox allows the user to customize the setup and replicate to other locations. Please click on the following link to access this full version:
https://bit.ly/2Ht7YyJ

User interface and results

The User Interface

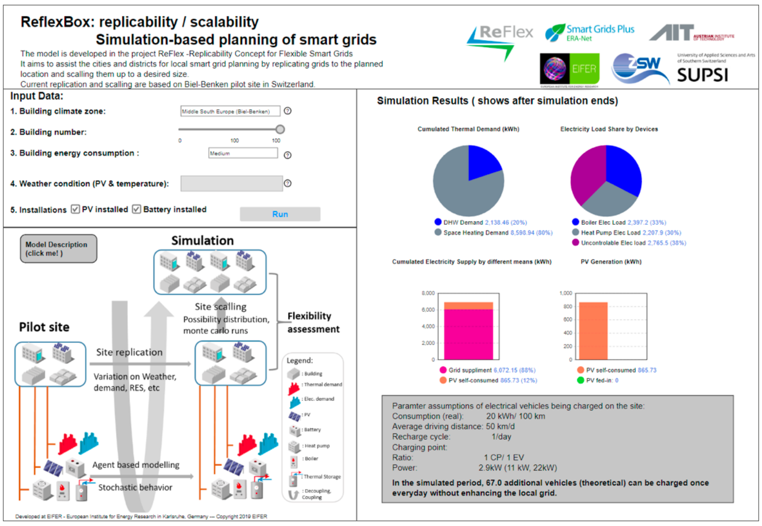


Figure 5
Illustration of the Impact of Electric Vehicles on flexible and unflexible Energy Systems

On the graphical interface of the ReFlexBox, the input parameters can be changed by the user. The user can select among 4 zones of central Europe that are implemented in the tool. The weather conditions refer respectively to those of the cities of Biel-Benken, Berlin, Warsaw and Malmö.

Input Data
The figures above show the graphical interface of the ReFlexBox and the input parameters that can be changed by the user. The user can select among 4 zones of central Europe that are implemented in the tool. The weather conditions refer respectively to those of the cities of Biel-Benken, Berlin, Warsaw and Malmö.
If the “User Defined Location” is selected, the user shall upload a customised weather file in format TMY (.tm2) in the corresponding “Weather condition” row. Data for other locations can be obtained from the Meteonorm database https://meteonorm.com/.

The user can choose the number of buildings and their energy consumption. The thermal energy consumption bases on a neighborhood of 100 houses in Biel-Benken, with an assumed average of 6470 kWh/year/house. Given this information as reference, the user decides whether the consumption is
"Very high" (20% higher consumption than reference),
"High" (10% higher),
"Medium" (equal to reference),
"Low" (10% lower consumption than reference) or
"Very Low" (20% lower)
Furthermore, PV and battery installations could be activated or deactivated by using the checkboxes.

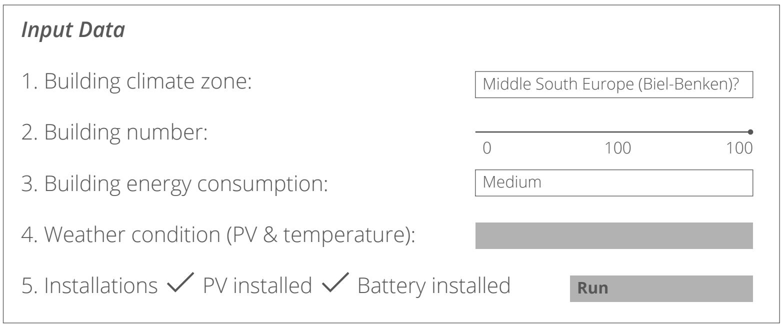


Figure 6
Model Input for Simulation

Simulation Results

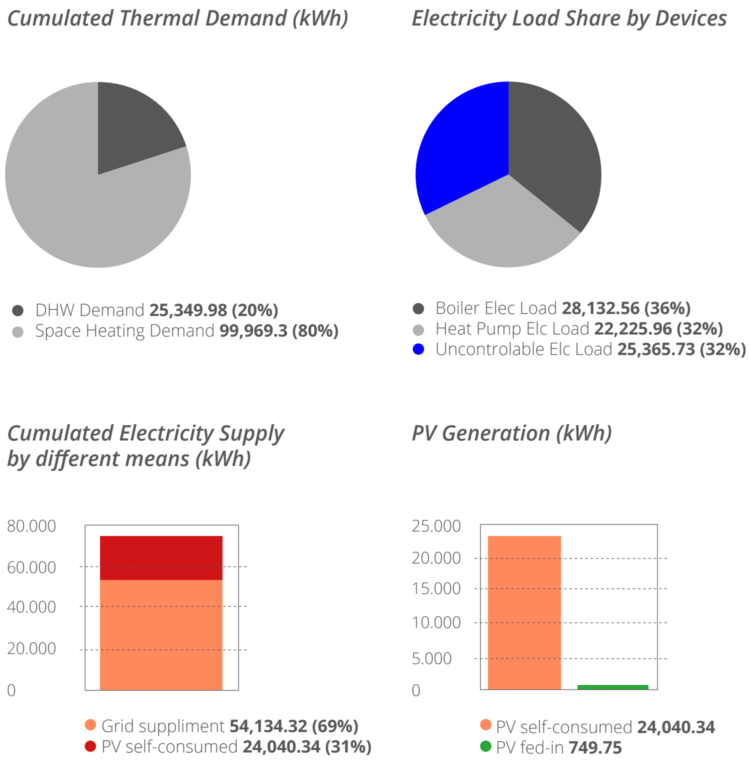


Figure 7
Visualized Energy System Performance

During the simulation, the user can observe the operation of the onsite energy devices over time including daily and seasonal change of thermal and electrical demand, PV generation, thermal and electrical storage state of charge, as well as the flexibility potential of the distributed energy resources. At the end of the simulation, yearly key performance indicators (KPIs) such as thermal and electrical demand, electricity supply from PV generation and the utility grid, overall flexibility from which the grid can benefit are assessed and visualised.
The flexibility potential of the simulated neighbourhood is quantified for each simulation time step, and the tool indicates at the end of the simulation how many additional electric vehicles can be implemented onsite without the need to reinforce the local grid. Model assumptions for electric vehicles base on German statistics and are listed in the below box.

Paramter assumptions of electrical vehicles being charged on the site:
Consumption (real): 20kWh/100 km
Average driving distance: 50 km/d
Recharge cycle: 1/day
Charging point:
Ratio: 1CP/1EV
Power: 2.9kW (11kW,22kW)

In the simulated period, 8 vehicles (guaranteed) can be charged once everyday without enhancing the local grid.

Figure 8
Parameter assumption for electrical vehicles adding to the local grid and its permissible number not influencing the grid impact

Several simulations were carried out to measure and compare the flexibility potential of different sites and system configurations. The scenarios and results are summarised in the table below.

Interesting scenarios by replicating a grid from Biel-Benken to Malmö show the deduction of flexibility potential by less 10%, which is caused by higher thermal consumption in Malmö. While replicating the smart grid solution to two different meteorological areas, we can still see a relevant flexibility potential in both, making the deployment of smart grid solutions interesting throughout the different countries. Two use cases of a grid consisting of 100 single-family houses located in Biel-Benken, with and without battery and PV installation are compared. The result shows that the battery and PV system doubles the grid's flexibility potential. In term of implementable electric vehicles, the grid without battery and PV allows 31 additional vehicles while the one with battery and PV allows 64 additional vehicles.

Table 2: Examples of Simulation Results

Scenarios			**Results**
Location	**Number of households**	**System configuration**	Permissible number of EVs that can be charged simultaneously without impact on grid stability
Biel-Benken	100	With PV and battery systems	64
Malmö	100	With PV and battery systems	60
Biel-Benken	100	Without PV and battery systems	31

6 Final Recommendations

Final Recommendations

Replication of flexibility solutions is an economically feasible and efficient way towards future-proof energy solutions. Building on innovations that already have been shown promising in pilots and demonstration projects in one site, helps to avoid repeating mistakes others already paid for. The following spotlights summarise some of the learnings, which practitioners in municipalities, energy system actors, technology providers and supportive researcher should take up when setting up a replication projects.

Spotlight #1: Demonstration and pilot projects cannot be copied! – How to compensate?

Demo Sites are based on specific context-conditions. Find out how you can compensate for peculiarities in context conditions on which pilots' successes depend!

Financing:

As piloted use-cases are by definition not yet profitable, they depend on public funding. Find out how you can compensate for R&D funding, e.g. by other forms of risk finance!

Unconventional organisational and personal constellations:

Overlaps of economic and political key actors can make innovation processes easier and faster in the first place. Find out how you can create similar conditions, e.g. by creating trust between replication partners and do not underestimate the value of cooperative climate!

Incentive structure:

Financial incentives, e.g. to end-users, for creating laboratory conditions in demo sites can make perfect sense for testing solutions, but not for replicating them under real world conditions!

Medium- and Long-term orchestration:

For systemic solutions, key-actors' shared visions on long-term transformation of the local energy-system are crucial. Find out how to build those visions and/or otherwise orchestrate actors in replication projects! Pioneering spirit: Involved staff and end-users with pioneering spirit is highly motivated, interested and often higher educated than will be the average user of a solution will be when deployed. Find out how to mobilise other resources, when developing a sustainable solution!

Spotlight #2: Compatible & Adaptable Context-Dimensions – What to look at?

Context conditions for replication projects need to be compatible & adaptable in the dimensions outlined in this guidebook:

Geography and Space – Climatic and topographic conditions as well as adequate spatial dimension; Technology – Energy infrastructure configurations, interoperability of components and the technological know-how; Policies of Actors – Governance processes, citizens' acceptance, trust in institutions;

Economic:

Costs of coordination, culture and willingness for co-creation, micro- and macroeconomic profitability, distribution of macro-economic benefits; Institutional Structures – EU and national legislation on competition and energy market regulation, energy market institutions, standardisation;

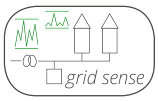
Actors and Stakeholders:

Actor-constellations, actor- & stakeholder network; People: entrepreneurial practice, cultural norms and peculiarities, social practices and behaviour of end-users and prosumers.

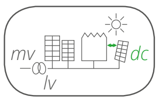
Spotlight #3: Role of Flexibility in Use Cases – Which kind of flexibilities?

A differentiation of two kinds of flexibilities can be provided by the use-cases. Flexibility for Power enables to match generation and loads on time, across seconds and minutes in the power-grid. Flexibility in Energy-logistics / Flexibility for Energy enables the overall balancing of the energy system (including the electricity and heat system) by energy generation and use across a period: minutes, hours, days and seasons.

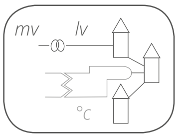
The aim of these energy system services is to manage variability and uncertainty in the energy systems:



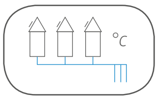
#1. ***Short term voltage-stabilization in local electricity grid:*** Aiming at stabilising the grid it serves as use-case for flexibility for power, mainly by managing the grid with actively engaging end-users by demand-response, which may effect social practices of household members.



#2. ***Energy management for business parks:*** Aiming at load and energy management b2b-services the use case provides flexibility for energy-logistics without having to actively engage end-users on a day-to-day basis.



#3. ***District heating load management:*** Aiming at load and energy management b2b-services the use case provides mainly flexibility for power in an integrated heat and electricity system, while it can also provide flexibility services for energy-logistics. The use case is based on using building structure as intermittent heat storage without bothering the end-users' comfort.



#4. ***Shared use of local low temperature resources:*** Mainly aiming at the use of a cheap energy source and potential heat- and cold storage, the use case can provide flexibility for energy-logistics with active engagement of the end-user. However, heat-pumps could potentially also be used for flexibility of power.

Spotlight #4: Success-factors for Flexibility-Solutions – How to Co-Create?
As flexibility solutions, for a foreseeable time, will not become available from the shelf, they will require tailoring to the needs of those who want to replicate existing solutions. It also requires reconsidering the roles of new and incumbent actors, which increasingly overlap (e.g. prosumers) and change. Thus, the question is to be answered how new coalitions are built, how they collaborate and compete. In the ReFlex demo-site this always involved co-creative innovation processes. Success will be based on a co-creative innovation process between involving those actors and other key stakeholders in multiple dimensions: Shared Visions & Missions-Models – Shared visioning and road-mapping processes involving all actors can help orchestrating energy system improvements in a sustainable way. A mission-model canvas, which outlines the monetary and social benefits, instead of considering the end-user merely as customer as ultimate source of profits.
Learning from & with Practitioners in Communities of Practice (CoP) – CoPs structure peer-to-peer learning among practitioners in a trustful face-to-face atmosphere. It is the key to learn from failures other already made, it is crucial for understanding of the importance of context factors and is a source for new innovative ideas. This cannot be replaced by reading guidebooks, expert advice or ICT-supported exchange platforms.
Co-Creation & unconventional co-operation – Innovation activities can build on a broad range of technological solutions on the one side but with the emerging new use-cases on the other side and new actors involved, establishes models of how innovations are developed changes. Particularly, as in some of the use cases there is a potential to provide flexibility services of different kinds, unconventional cooperation might be beneficial and co-creation becomes more likely.
Overlapping Networks (Policy, Economy, Research, …) – As the energy system is in transition, so are the networks of actors and stakeholders providing the innovation-ecosystem. This involves networks in policy making, industry, energy sector and research. Although many actors are involved, those who are able to link between those regionally, sectorial or disciplinary constituted networks play an important role in adapting the context-conditions for replication.
Collaborative Business Models – Demonstration and Pilot projects for the use-cases do not yet constitute feasible business-models. However, they show that collaboration and cooperation are key to create new value propositions and societal benefits. Therefore replication processes should consider developing collaborative business models with fair distribution of benefits between all actors. This includes co-operation between municipalities and energy sector actors as well as end-users or prosumers when providing flexibility services for others.
Room for Experimenting – As context conditions are critical for the replication of flexibility solutions, more and more policy makers recognise the need new instruments to create room for experimenting. This includes funded Experimental Sandbox programs (like in UK and Singapore) and laws for regulatory exemptions (like in the Netherlands and Germany). When planning replication projects, those possibilities should be identified and evaluated.

7 Annex:
Technologies Review

The Replication of Technologies

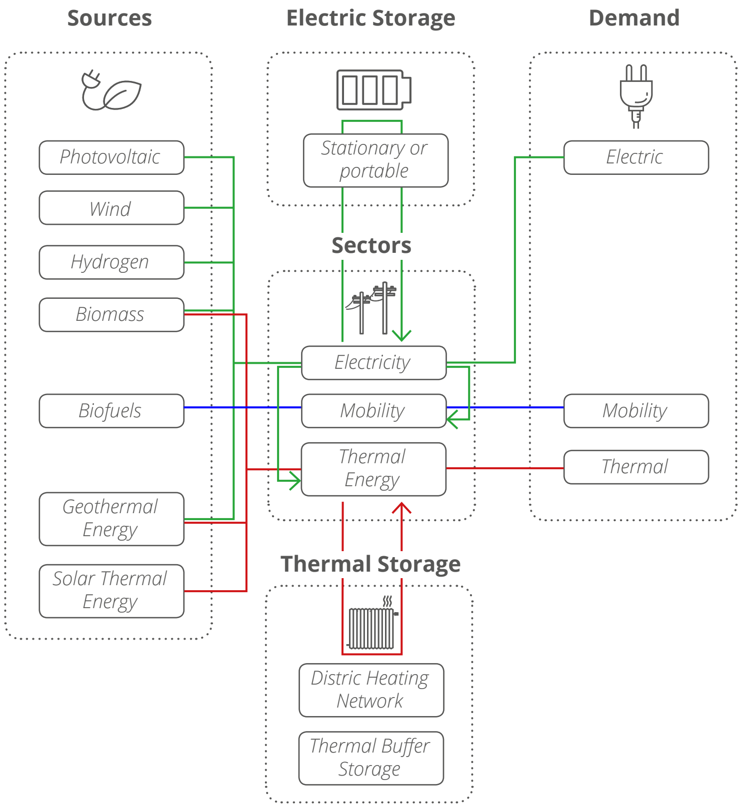


Figure 1
Sector coupling within the demo sites showing also the used energy sources, sectors and covered demands.

Photovoltaic

To estimate the potential of PV systems, run a performance analysis to identify the best locations for solar installations. Seasonal fluctuations are substantial due to the different hours of sunshine from summer to winter. Regional differences lead to fluctuations in the performance of PV systems, as the hours of sunshine depend on both, weather and geographic location.
For PV systems, areas with high solar irradiance are preferred. Therefore, residential or industrial buildings with suitable rooftops or open space areas need to be exploited.
The profitability of a PV system depends on the installation costs, energy yield and electricity price. At most demo sites, residential or car-park PV systems focused on the optimisation of self-consumption.

Hydro

There are two types of power plants using hydropower to generate electricity. Firstly, run-of-river hydroelectricity with small or no water storage and secondly, pumped-storage hydroelectricity. Hydroelectricity power plant could also be used for sector coupling such as power-to-gas especially for seasonal storage of energy. Nevertheless, hydroelectricity is not used within the demo-sites and therefore could not further be evaluated.

Demo Site Examples Photovoltaic:

Open Space
Güssing: Currently the region's largest PV plant with a rated power of up to 2,5MW
Hartberg: Carport with integrated PV station for re-fueling electric vehicles
Köstendorf: High density of PV systems, should be installed on every second roof
Gotland: PV system was designed to resemble a typical micro production, to determine if modern smart meters can be used to identify and correct power quality variances

Roof top
Biel-Benken: Using PV systems for self-consumption with and without energy storage in batteries and electric vehicles
Hyllie: "A significant share of the energy production will be locally produced in the form of such solutions as solar photovoltaics on the properties"
Wüstenrot: Roof top PV-installations with battery storage systems

Solar Thermal Energy
All demo sites only use small-scale solar thermal collectors for domestic heat supply. Seasonal fluctuations are substantial due to the varying hours of sunshine from summer to winter. Regional differences lead to fluctuations in the performance of solar thermal collectors, as the hours of sunshine depend on both, weather and geographic location.
For solar thermal collectors, areas with high solar irradiance are preferred. Therefore, residential or industrial buildings with suitable rooftops or open space areas need to be exploited.
The profitability of solar collectors depends on the installation costs, energy yield and costs for heating.

Demo Site Examples Solar-thermal

Güssing: Solar thermal system with 40m² collector area and 3000m³ hot water tank as hot water used in a gym and space heating.
Hartberg: Desiccative Evaporative Cooling system (DEC) with 12m² flat plate collectors.
Hyllie: Apartment blocks equipped with solar thermal collectors.
Wüstenrot: Injecting solar thermal energy into a heating grid.

Biofuel and Biogas
If renewable energy sources are used to provide fuels, e.g. for mobility, they are called biofuels.
Biofuels could be produced out of electricity by sector coupling such as power-to-gas and power-to-liquid, but also directly from biomass using thermochemical processes. The needed carbon dioxide (CO2) source could be supplied by efficiently by a nearby biogas plant.
The efficiency of the biofuel production mainly depends on the used technology, the CO2 source and steady energy supply. That's why it could be beneficial to buffer the fluctuating renewable energy sources by battery storage and/or locate the plant in a rural area with enough accessible biomass nearby. As the efficiency is rather small compared to direct energy use for movement, heat or electricity, an overlap of installed renewable energy plants is recommended. Because handling and storing gas and fuels are well known and therefore are suitable solu-

tions for seasonal energy shift. Biofuel and Biogas production could also be a showcase for good regional cooperation of nearby municipalities.

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Biomass

The supply of biomass is the biggest obstacle for replication. The different types of biomass are subject to seasonal variations such as e.g. agricultural products (corn) and therefore not permanently available. Other biomass products such as e.g. fuel alcohol from agricultural products can be stored over a long period and are thus seasonally independent. However, the endeavour to supply enough food to the steadily growing world population means that the availability of biomass from agricultural products is becoming increasingly scarce.

Limits of biomass exist only in the procurement of raw material and energy distribution; the power plants can be built almost arbitrarily large. Biomass can be burned directly or converted to liquid biofuels or biogas. The most efficient way to use biomass as an energy source is a combined heat and power plant (CHP) with a heating grid.

The costs of biomass as an energy source are mainly dependent on raw material prices of the used type biomass (e.g. wood chips, grass). Independence of energy supply, regional jobs and sustainable development of a region cannot be measured by financial aspects only.

Demo Site Examples Biomass:

Güssing: Thermochemical biofuel production supplied by local biomass (mostly grass) and biogas plant.

Local Geothermal Energy

Local Geothermal energy systems use heat in the ground. In general, there are two types of local geothermal energy systems. On the one hand, to provide heat to individual users and on the other hand to provide heat to several users connected to one source. The replication of the first type is based on individual requirements. However, the connection of a local geothermal source to multiple premises only makes sense in combination with a local heating network. Geothermal energy sources could be near the surface (e.g. an agrothermal collector) or deep down whereby the temperature increases with depth. Hence, near-surface geothermal collectors provide a low but constant temperature ideal for electric heat pumps heating the buildings in winter or cooling down in summer. The heat provided from deep geothermal sources can often be used directly without the need for heat pumps. If available, groundwater is used as heat transfer fluid but also closed loop systems are common, especially in nature conservation areas.

As the efficiency of geothermal energy systems is based on the used technology and its geographical location, a potential analysis is recommendable. The underground limits the size and number of energy systems at one location. From an environmental point of view, a heating network does not present any danger to the environment during normal operation. However, in the event of a leak, environmental impairment such as landslides and impacts on groundwater could occur. An emergency plan is obligatory. All relevant legal regulations of the country must be observed, and all contracts must be legally concluded.

As geothermal energy systems have to meet high safety standards and also needs excavation work- Excavation costs increase with the depth and soil quality. Depending on heat generation and installation costs a minimum number of end-users for a profitable heating network is required.

Demo Site Examples Local Geothermal Energy:

Wüstenrot: A near surface geothermal energy system with an agrothermal collector as shared low temperature source provides heating/ cooling for private households using heat pumps and a district heating network.

ReFlex Project Partners

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